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INSPECTION OF AIRCRAFT AFTER OVERHAUL'

CATEGORY "B" LICENCE

BY

S. J. NORTON

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The Air Ministry, whilst accepting no responsibility for the contents of this book, recognizes it as a textbook that should prove to be of value to intending applicants for Ground Engineers' licences

(FOURTH EDITION)

PREFACE

THIS instructional work has been prepared as a guide to intending applicants for the Category "B" Ground Engineer's Licence.

Air Ministry Pamphlet 34, which is entitled "Instructions to Applicants for Ground Engineers' Licences and Syllabus of Examinations," is usually sent to every applicant for a ground engineer's licence. It points out that all applicants will be required to show that they have obtained and studied the Air Navigation Order and the Air Navigation Directions issued thereunder, which detail the duties and qualifications of ground engineers, and provide for all concerned information regarding the regulations governing Civil Aviation. It is essential that prospective ground engineers should have a satisfactory knowledge of these regulations.

It further indicates that applicants should obtain the "Airworthiness Handbook for Civil Aircraft" (A.P. 1208), which contains valuable information in connection with the inspection of aircraft and aero engines. The Airworthiness Handbook is of particular importance and value to aspirants for licences in category "B." These publications can be obtained from His Majesty's Stationery Office, York House, Kingsway, W.C.2, or through any bookseller.

The directions require that as regards category "B" the applicant must have had such practical experience on aircraft maintenance and construction as, in the opinion of the Secretary of State, will enable him to perform satisfactorily the duties for which the licence is required.

It is further important that the candidate should understand clearly what duties come within the scope of the particular category in which he is to be examined, as there is the danger of exceeding those duties and overlapping into categories for which he has not been certified.

It must be realized that whereas the category "A" ground engineer is only entitled to replace aircraft components or parts which have been previously inspected and approved, the category "B" man is responsible that such components or parts are made from the correct materials, and that the processes employed in manufacture have been carried out satisfactorily.

For this purpose he must be able to satisfy himself that the materials used in construction comply with the specifications, either by documentary evidence such as approved release notes coupled with inspection and identification stamps on the material, or by the examination of the results of tests which on occasion he may have

to instigate or perform. In some instances, e.g. timber, he may himself be responsible for selecting the material to be used.

During the inspection of an aircraft and its accessories after repair or overhaul, he should ensure that no departure has been made from the type aircraft without official authority.

Another feature demanding attention is that of the category in which the aircraft is certified, such as "Special" or "Normal" categories, coupled with the particular subdivisions of these categories.

The Syllabus for a candidate entering the category "B" examination lays down that to qualify, the candidate should understand the general principles of the inspection of aircraft construction, including the following—

1. Knowledge of non-metallic materials; methods of identification, examination, and testing; characteristic defects which render them unsuitable; and precautions to be observed in their application to aircraft construction.

2. Knowledge of metallic materials; methods of identification, examination, and testing; characteristic defects which render them unsuitable, and precautions to be observed during processes of manufacture (heat-treatment, welding, brazing, soldering, plating, etc.).

3. For licences to include seaplane endorsements, knowledge of the methods of construction and examination of hulls and floats is also required.

4. Knowledge of the methods of construction, examination, and testing of aircraft parts and components (fuselages, wings, propellers, tanks, radiators, pumps, cocks, etc.).

5. For licences to include aircraft of all-metal construction, knowledge of the high tensile steels and aluminium alloys, and the special workshop processes applicable to the materials, is required.

6. Knowledge of methods of inspecting and testing the complete aircraft for correct assembly; installation of engine, controls, fuel, oil, and water systems, instruments, electrical services, and other appliances.

In conclusion it should always be fully realized that the methods of inspection must of necessity vary to keep pace with the improvements in design and construction, and that the ground engineer, to maintain efficiency, must devote the requisite attention to these changes as and when the information relating thereto is circulated.

Copies of D.T.D. Specifications can be obtained through H.M.S.O., Kingsway, London, W.C.2, and copies of B.S. Specifications from The British Standards Institution, 28 Victoria Street, London, S.W.1.

NOTE. Where Specification Numbers are quoted in this volume the latest issues of the Specifications are always implied.

CONTENTS

vii

INSPECTION OF AIRCRAFT AFTER OVERHAUL

NON-METALLIC MATERIALS

THE materials used in aircraft construction may be divided into two classes, Non-metallic and Metallic.

Under the heading of non-metallic materials are the timbers, plywoods, fabrics, dopes, glues, rubber and other flexible hose (for use with petrol, oil, and water), varnishes, paints, rubber shock absorber cord, fibre, and leather, for which, with the exception of the last two, there are B.S. or D.T.D. Specifications.

TIMBERS

The timbers used in the construction of composite aircraft are chiefly spruce and ash, while for the construction of wooden airscrews mahogany and walnut are used. In the selection of rough timber in the bulk, attention should be paid to the general characteristics of each piece, with a view, as far as is possible, to selecting a quality which conforms to the applicable specification. Such factors as the method of seasoning; conversion; weight per cubic foot; rate of growth, which is judged by the annual rings; direction of grain; amount of sapwood, and the characteristic defects, must receive due attention at this stage to avoid, as far as possible, the scrapping of parts during manufacture.

Testing of Timber

The tests carried out on timber to ascertain that it complies with the specification, and is suitable for use on aircraft, are as follows—
1. Moisture content test.
2. Density (lbs. per cubic foot).
3. Tests for Young's Modulus, and modulus of rupture.
4. End grain compression test.
5. Brittleness test.

The required minimum results of these tests are laid down in the specifications for the particular timbers, and briefly are as follows—

The methods of determining these results are laid down in the respective British Standard Specifications, and for the benefit of the reader are reprinted in the following pages by courtesy of the British Standards Institution. The methods of carrying out the tests are standard for the timbers already mentioned. (Copies of British Standard Specifications can be obtained from British Standards Institution, 28 Victoria Street, London, S.W.1.)

METHOD FOR MEASURING MOISTURE CONTENT

A small sample of the timber shall be removed from the position indicated by the inspector and weighed (W_1). The sample shall then be

TABLE I

TIMBER	SPECIFICATION	MOISTURE CONTENT	DENSITY (Lbs. per cub. ft. at 15% moisture content)	END GRAIN COMPRESSION (Lbs. per sq. in. strength not less than)	YOUNG'S MODULUS (Lbs. per sq. in.)	MODULUS OF RUPTURE (Not less than lbs. per sq. in.)	BRITTLENESS (Ft. lbs.)		AT A MOISTURE CONTENT OF*
							Method A	Method B	
Silver Spruce .	D.T.D. 36.A.	14 to 17%	24	5,000	Not less than 1,500,000	8,000	13	0	15%
Ash .	B.S.S.3.V.4.	Not more than 16%	40	5,800	1,500,000 to 1,900,000	10,500	17	8	15%
Walnut .	B.S.S.3.V.5.	Not more than 13%	35	7,000	Not less than 1,500,000	11,500	15	7	15%
Mahogany .	B.S.S.4.V.7.	Not more than 14%	32	6,250	Not less than 1,500,000	10,000	8	4	15%

* For test figures at other moisture contents see particular specification.

desiccated in an oven at a temperature of approximately 100° C. to 105° C. (212° F. to 221° F.) until the weight is constant (W_0).

The percentage of moisture shall be calculated as follows—

$$\text{Percentage of moisture} = \frac{W_1 - W_0}{W_0} \times 100$$

For the determination of moisture content of test pieces the sample shall be taken on a transverse section near the fracture.

Great care should be taken to prevent any change in moisture content between the cutting of the sample and the first weighing or between removal from the oven and the subsequent weighing.

METHOD FOR DETERMINING END GRAIN COMPRESSION STRENGTH

Three test pieces shall be turned from each sample to be tested.

The test pieces shall be prepared to the dimensions shown in Fig. 1, the ends being turned quite flat, the small centre pip being smoothed off with a chisel; or, alternatively, the test pieces may be cut 1 in. square and 2 in. long. If the faces are not quite parallel, or if the testing machine does not load the sample quite evenly, the sample may be fitted with end collars.

It should be noted that, if the sample is not loaded evenly, the results will be lower than the true value, and if the load is applied too rapidly the results will be higher than the true value. At the specified rate, the test takes about one minute, and a close watch should be kept on the beam of the testing machine when approaching the maximum load and the loading stopped at the moment the beam begins to drop.

FIG. 1. END GRAIN COMPRESSION TEST PIECE

(By courtesy of The British Standards Institution)

During the test the load shall be so applied that the stress in the test piece increases at a rate of from 3,000 to 6,000 lb. per sq. in. per minute. The ultimate compression stress for the timber shall be taken as the average of the three tests, the corresponding moisture content being taken as an average of the moisture content of the three test pieces.

METHOD FOR DETERMINING YOUNG'S MODULUS OF ELASTICITY AND THE MODULUS OF RUPTURE

The test piece shall be 40 in. long and shall have a rectangular section 2 in. deep by 1 in. wide, or preferably a square section 2 in. by 2 in. It shall be cut with the length parallel to the longitudinal direction of the grain of the timber and preferably with the depth parallel to the radial face of the test piece, the heart side being uppermost.

The beam test should be carried out wherever possible with four point loading in order to avoid additional deflection due to lateral shear in the middle part of the beam where the deflection is measured. The load shall be applied in the neutral plane of the beam in such a manner as to prevent longitudinal loading of the beam and local crushing of the timber, and at such a rate that the loading head descends at a constant speed of 0·13 ± 20 per cent inch per minute. A suitable apparatus is illustrated in Fig. 2.

A series of deflections corresponding to a series of increasing loads should be measured on a portion of the beam between the central loading points. Results when plotted should lie on a straight line up to the elastic limit.

If W_1, W_2, and d_1, d_2 are the loads and corresponding deflections for any two points on this straight line the value of E is given by

$$E = \frac{3}{4} \frac{(W_1 - W_2)}{(d_1 - d_2)} \frac{al^2}{bh^3}$$

where a = distance between the outer point of support and the adjacent inner loading point (see Fig. 3),
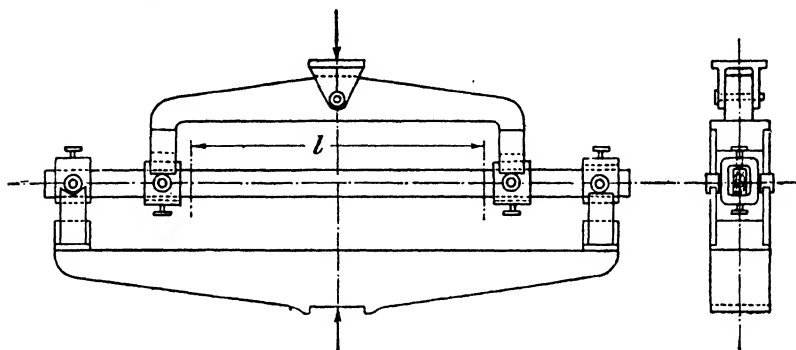
FIG. 2. BEAM TEST MACHINE
(*By courtesy of the British Standards Institution*)

l = length (of the neutral axis) at the centre of which the deflection has been measured,
b = breadth of beam,
h = depth of beam,
all dimensions being in inches.

The modulus of rupture may be calculated as follows: Modulus of rupture = $\dfrac{3\,Wa}{bh^2}$ where W is the load required to break the test piece.
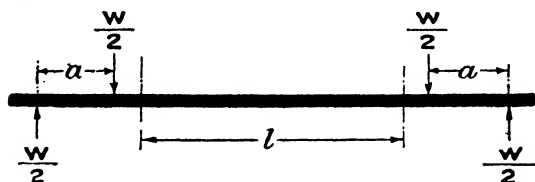
FIG. 3. BEAM TEST DIAGRAM
(*By courtesy of the British Standards Institution*)

METHODS FOR DETERMINATION OF BRITTLENESS

Method A. A plain test piece, cut parallel to the grain, to the size given in the specification, shall be prepared, with the sides cut radially and tangentially, and the blow shall be applied in the tangential direction.

The testing machine shall consist essentially of a free falling, vertically guided weight of 24 lb., the striking surface of which shall be cylindrical with a radius of 3 in. The weight shall be dropped through 4 in. for Mahogany, $6\frac{1}{2}$ in. for Spruce, $7\frac{1}{2}$ in. for Walnut, and $8\frac{1}{2}$ in. for Ash; on to the above test piece, when the latter is placed centrally on supports 10 in. apart. These supports shall have a $\frac{1}{4}$ in. radius on the inside upper edges.

The machine shall stand firmly on a concrete floor, or its equivalent. An illustration of a suitable machine is shown in Fig. 4.

IMPACT TESTING MACHINE.
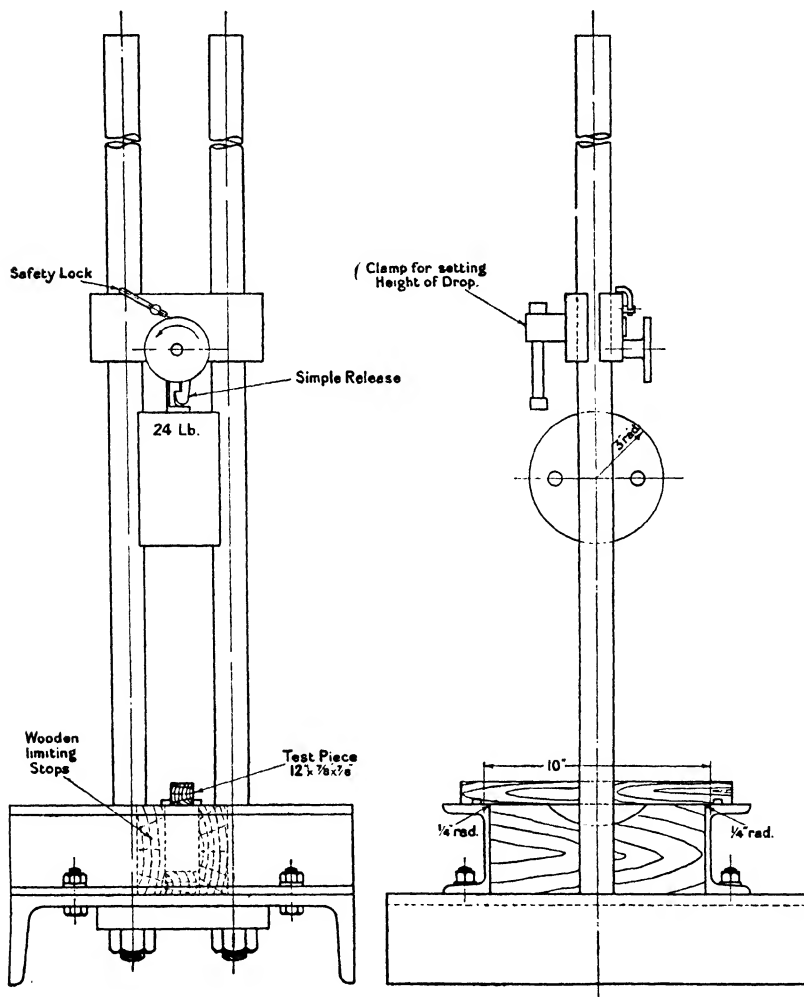
FIG. 4. SIDE AND END ELEVATIONS OF SIMPLE DROP
IMPACT TESTING MACHINE
(*By courtesy of The British Standards Institution*)

The opening out of a few fibres on the under or tension side shall not be taken as indicative of failure.

Method B. A notched test piece, the sides of which are cut radially and tangentially, of the dimensions shown in Fig. 7 shall be broken in an
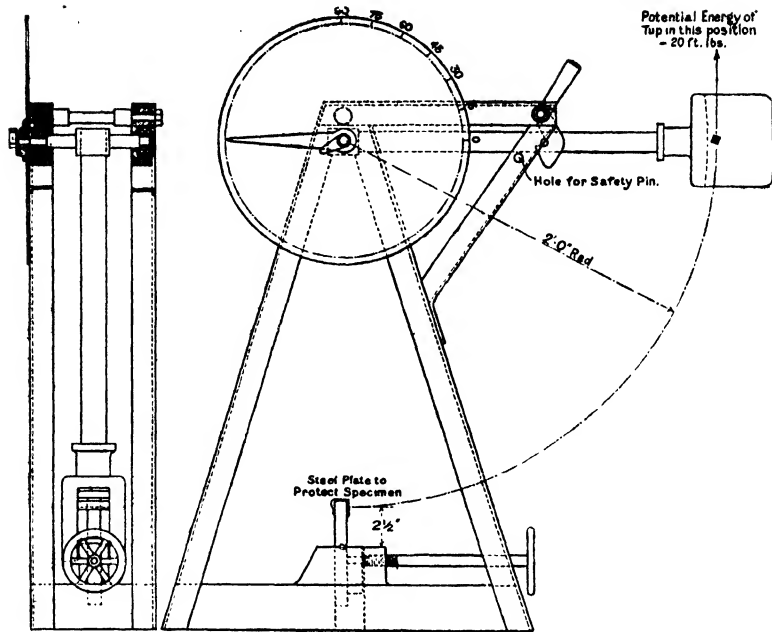
FIG. 5. SIDE AND END ELEVATIONS OF IMPACT
TESTING MACHINE

(*By courtesy of The British Standards Institution*)

NOTE.—When Scale is marked in Degrees as shown, work expended in breaking specimen
= 20 sin a (a = reading on scale at which Pointer comes to rest).
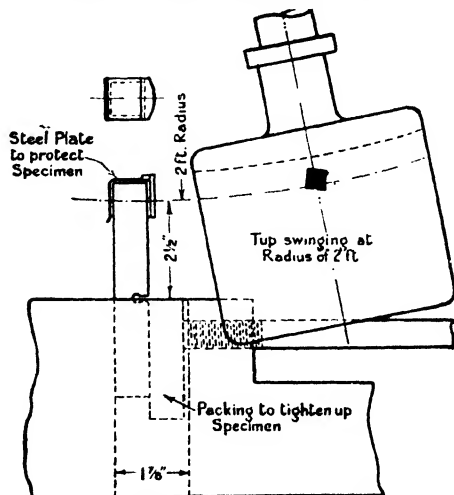
FIG. 6. ENLARGED VIEW SHOWING TEST PIECE IN POSITION
IN TESTING MACHINE

(*By courtesy of The British Standards Institution*)

impact testing machine of the type illustrated in Figs. 5 and 6, the blow being applied in the tangential direction.

The Standard Specifications for the materials used in aircraft construction are subject to periodical review and possible amendment in order to keep abreast of progress. In this work, therefore, only typical examples of the tests laid down in such Specifications are given in order to assist the ground engineer to understand the function of the tests called for, and to realize more fully his exact duties when dealing with release notes and test reports.

Should there be any reason to doubt the condition of the timber during production of the finished parts, even though it has been previously approved, further check tests should be carried out.

Blow to be struck in a direction Tangential to Annual Rings

Tup strikes here

⅛ dia.

Saw Cut

ENLARGED VIEW OF NOTCH

FIG. 7. STANDARD TEST PIECE

Spruce

This timber, which is used for the chief structural members of a composite aircraft, is known as Sitka spruce, a large percentage of which comes from British Columbia.

It is imperative to watch that the timber is free from dote and any form of decay, shakes, deleterious knots, and resin pockets. The timber must, further, be straight in grain and fibre. Dote is a disease which, when present in spruce, renders the timber very definitely useless for aircraft purposes. The inspector will have no doubt in rejecting timber if the dote is in the advanced stages of development, owing to the obviously decayed nature of the parts affected. The symptoms of dote in its early stages are detected in the form of yellowish or brownish spots which, however small, or indicating the slightest evidence of the disease, should cause the rejection of the member or members concerned, because the decay, once present, will spread.

The angle of cross-grain is determined by measuring the slope of the annual rings against the major axis of the piece of timber, and should not depart from the major axis by more than an inclination of 1 in 15.

The detection of spiral grain in finished spruce sometimes presents greater difficulty however. This defect is an inclination of the fibre of the annual rings, and if present is detected by examining the flower side or figured surface of a piece of timber. A more reliable check is to remove a short piece from the strut or member concerned, and split it with a chisel at right angles to the annual rings. It

INK SPOT

FLOWER SIDE

FIG. 8

A B

FIG. 9

may happen that such a specimen is not available; then detection must be made on the flower side of the timber by examination of the slope of the sap ducts. If it is impossible to discern the run of these sap ducts, a spot
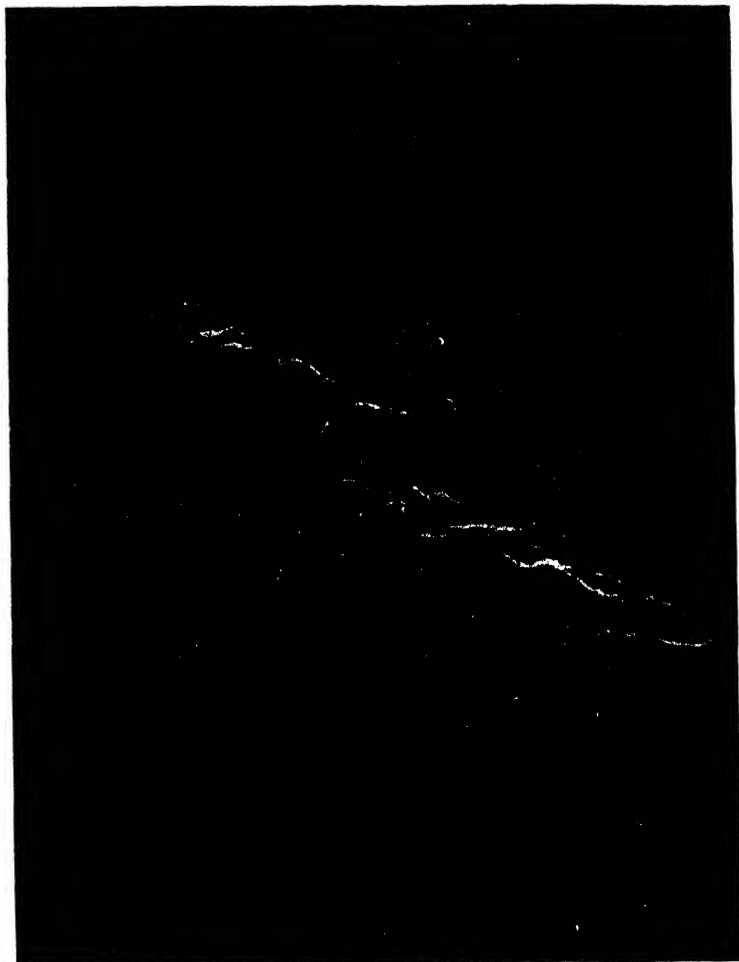
Fig. 10

of ink will facilitate the detection, because if applied to the flower side of the timber it will run in the true direction of the grain. (Fig. 8.)

Many telegraph poles display very clear illustrations of spiral grain. On the surfaces of these poles it will be noticed that the very evident shakes lie in more or less spiral directions. In Fig. 9, showing a short length of a pole, is indicated the travel of the spiral grain, while the cross-section shows the straight travel of the edge grain. While this feature may not impair the strength of a pole if left uncut, the result would be

very obvious in a plank $AA - BB$ cut from the pole. The maximum limit for spiral grain is also 1 in 15.

Spruce containing resin pockets, unless they are very small compared with the section of the member, should be rejected, as the percentage strength reduction is unknown, and may render the member weaker than the design requirements. Acceptance may be considered at the discretion of the inspector, if they occur at or near to the neutral axis of the member.

Although the presence of resin pockets may be betrayed by local irregularity in the grain, the greater dimension of a pocket is often hidden. It
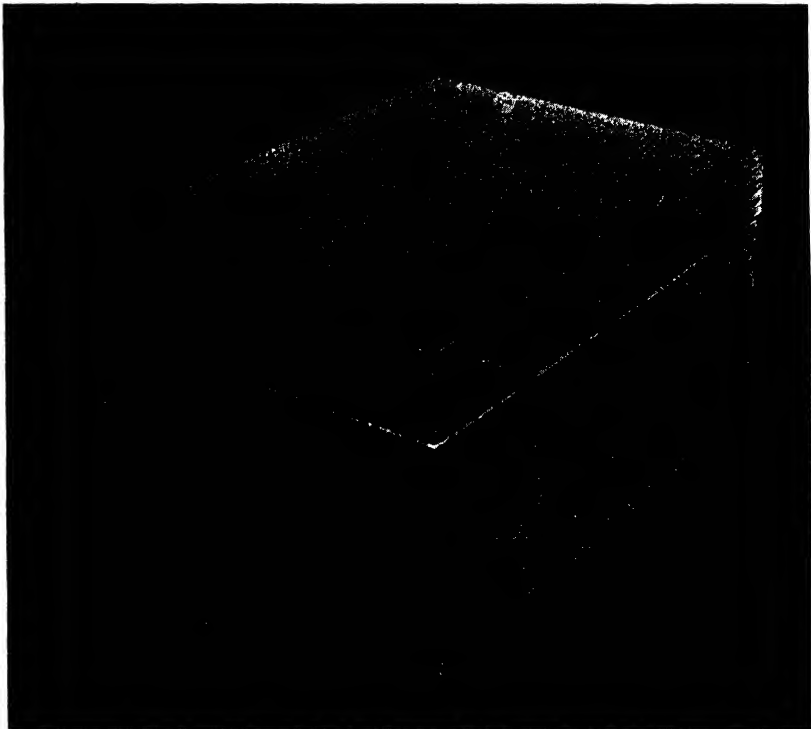
FIG. 10A

is imperative to explore the extent of a pocket before considering its acceptance.

Figure 10A shows a spruce specimen exhibiting the conditions mentioned, where further investigation has revealed the large pocket approximately 7 in. long, shown in Fig. 10B.

The danger of such hidden defects is not so great in modern design, however, since spars and struts are generally built up of comparatively thin laminations glued together. Since each lamination may be examined before gluing, there is every chance of detection of resin pockets and similar defects which are deleterious. Furthermore, hidden defects in thin laminations are less likely to cause serious diminution in the strength of the built-up member.
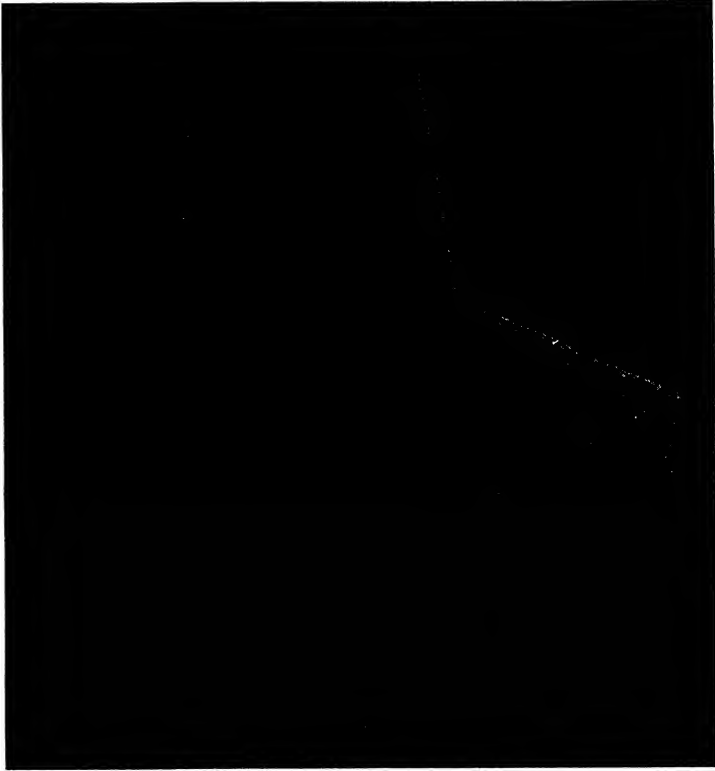
FIG. 10B
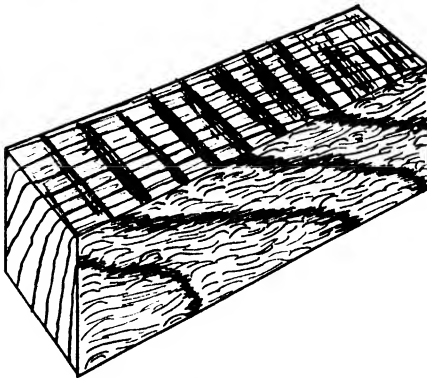
FIG. 11

Although it has been stated that resin pockets may be accepted in certain circumstances, spruce with resin veins should always be rejected, as these cause poor adhesion between the annual rings, with consequent risk of splitting down the grain.

A resin vein, as distinct from a pocket, runs with the grain in the form of a streak embracing one or more annual rings, and can be detected by discoloration.

Compression and felling shakes are detected by an apparent rupture of the edge grain in the part affected. (Fig. 10.)

The annual rings should not be less than 18 in any 3 in., while spruce with an excessive number of annual rings is often timber of low density.

It is important that spruce members, when finally shaped, should be adequately protected with an approved varnish, and in view of the timber being prone to gain or lose moisture, it should be protected as soon as possible after final shaping; varnishing should be carried out in a warm dry shop. The ends of wooden spars should be heavily coated with several applications of shellac or other approved material.

Ash

This timber should be cut from butt lengths of British-grown ash, which for preference has been felled between the months of November and March. It must be free from deleterious knots and shakes, and shall not contain any rammy or caney grain, nor show any signs of rot or decay.

Rammy or caney grain is illustrated in Fig. 11. Caney grain is just what its name implies, and is fairly clearly indicated on the end of the wood, which appears very porous. Ash with any of the above defects is useless, and should be rejected.

The annual rings of an ideal and strong ash are about four to the inch. The inclination of the grain to the length of the part being made must not exceed 1 in 10.

Ash is often required to be steam-heated for the purpose of bending. Care should be taken that the maximum temperature during steam-heating does not exceed 220° F. (2 lb. per sq. in.), and that the timber shall not remain under this heat any longer than is absolutely necessary, consistent with pliability. Parts made from this timber should be protected by an approved varnish as soon as possible after completion.

Walnut

The kind of timber used under this heading is almost exclusively American black walnut. It is mainly adopted for use in the manufacture of airscrews and for packing blocks. It is a very hard wood, and distinctly dark in colour, so that its identification is an easy matter to anyone with slight experience. The method of testing is similar to that already described for spruce, and the minimum results of such tests are mentioned in Table I, page 2.

This timber must not be reduced to its finished shape until the moisture content has been reduced to 13 per cent or less. Examination should be made periodically during conversion for deleterious knots, shakes, rammy figure, caney grain, rot, etc. The defects of rammy figure and caney grain have been described under the heading of " Ash," while the detection of the other defects will not be a matter of great difficulty to an inspector guided by experience.

Sapwood is not prohibited, providing it is sound, tough, and strong. Natural or artificial seasoning is permitted, providing authority is given for the particular method adopted. The maximum cross grain permitted is 1 in 12.

It is not possible, in the early stages of manufacture, to treat this material with a protective coating, but as soon as possible after its completion it should be varnished in order to avoid warping and variation in moisture content due to atmospheric conditions.

Mahogany

Honduras mahogany, which is obtained from Central America, is the timber most extensively employed in the manufacture of airscrews, and owing to its exceptional suitability for this purpose it has never met with much competition, although there are other varieties of this or like timbers

which might be equally suitable. It is also employed for the veneers of certain plywoods, and for packing blocks. The identification of the different kinds of mahogany by visual examination is no light task even for the expert, and the fact that often the same kinds of this wood vary considerably in colour renders distinction a job for one with considerable experience. Cedars have even been selected for mahoganies by mistake.

The properties required of an approved mahogany are shown in Table I, page 2, while the methods of obtaining the test results are as laid down at the beginning of this chapter.

Conversion to the finished shape must not be completed while the moisture content is above 14 per cent. The timber should be examined at definite intervals during conversion to the finished product for such
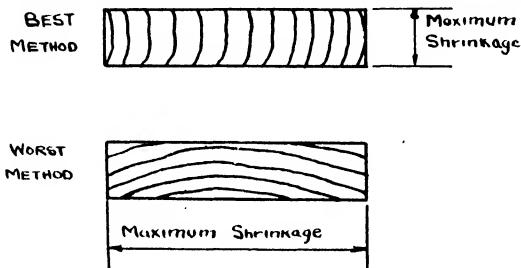
Fig. 12
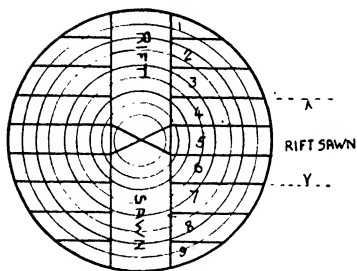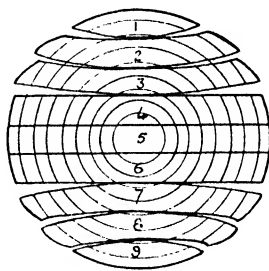
Fig. 13   Fig. 14

defects as wormholes, gum veins, various forms of rot, knots, shakes, fiddle-back figure, cross and curly grain. Sapwood is not permitted. Both natural and artificial seasoning are approved for use, but the exact method should be individually authorized. The average inclination of the grain must not exceed 1 in 12. A protective coating should be added to the finished product as early as practicable, as it prevents any change in the moisture content and thereby minimizes the chances of warping.

Conversion of Timber

Rift-sawn timber (see Fig. 12) is ideal for all purposes, but cannot generally be enforced. The components of built-up details, such as box spars, should, however, be as nearly as possible rift-sawn, or at least with the angle of the annual rings not less than 45° with the broad surface of the section. Deep I-section solid spars are also cut to the best advantage in the same manner.

The principal advantage of rift-sawn timber in the construction of aircraft details is that it compensates for shrinkage. The ratio of shrinkage

in most timbers is greater in a tangential than a radial direction, therefore in the end section of a rectangular piece of timber the greater dimension should be radial, as is indicated in Fig. 13.

As already mentioned, the above is ideal, but cannot always be carried out economically, for instance, in the construction of airscrews; but if the principle is understood, a good deal can be done in the matching up of the various laminae.

With the above end in view, a popular method of cutting a log to produce as much rift-sawn timber as possible is illustrated in Fig. 13. This is, of course, a compromise, but it has been found an economical method of conversion, and produces timber of moderate width. It is generally found that the centre of the log, marked ✕, is defective.

If a log is flat sawn as in Fig. 14, the outer planks 1, 2, 3, 7, 8, 9, will warp as they dry, the side nearest the heart becoming convex. This is more pronounced in the hard woods, but the same principle applies more or less to all timbers. The centre planks 4, 5, and 6 will remain flat when seasoned.

PLYWOOD

This material is usually constructed of three veneers of wood glued together while under pressure. The grain of the outer plies runs longitudinally with the length of the board, while the grain of the middle ply is at right angles to that of the outer plies, or across the board.

Where more than three plies are used, the material is termed "multi-ply." For the outer faces of three-ply, birch, mahogany, and teak are used, the latter always being employed together with a "soft core" or middle ply. Birch is used for the middle ply of "hard core" material, while such timbers as basswood, mahogany, and poplar form the centres of "soft core" plywood. Combining the veneers in this manner produces a very strong material.

There are various qualities, or grades, of plywood, but for the purpose of general description they may be divided into two main classes, the first being plywoods which are employed on structurally important parts of aircraft, such as fuselage sides and in spar construction, and the other class, which is used for unstressed or only lightly stressed parts, such as fairings.

The first of these classes is tested for the adhesion of plies, resistance to water, resistance to dry heat, and for moisture content, while the

Fig. 15

$X = 1$ in. or 8 times the thickness of board, whichever is the smaller

quality and thickness of the timber plies, and the direction of grain, also demand attention. The adhesive strength should not be less than 200 lb. per sq. in. of glued surface when a specimen prepared as shown in Fig. 15 is tensile tested. Further, when the veneers of the board are forcibly separated appreciable resistance should be offered to separation and the fractured surfaces must show adherent fibres of the wood distributed over the glued surfaces.

The plywood is tested for resistance to water by immersing two samples in boiling water for three hours, during which period no appreciable signs of separation of the plies should be evident. On the completion of this test, one of the specimens is plunged immediately into cold water, and after cooling, and while still wet, tensile tested in the manner described above, showing an adhesive strength of not less than 100 lb. per sq. in. of the glued surface.

The method of determining the resistance to dry heat is that of drying selected specimens for three hours in an oven at a temperature of 100° C. to 105° C. and allowing the specimens to cool to room temperature, when
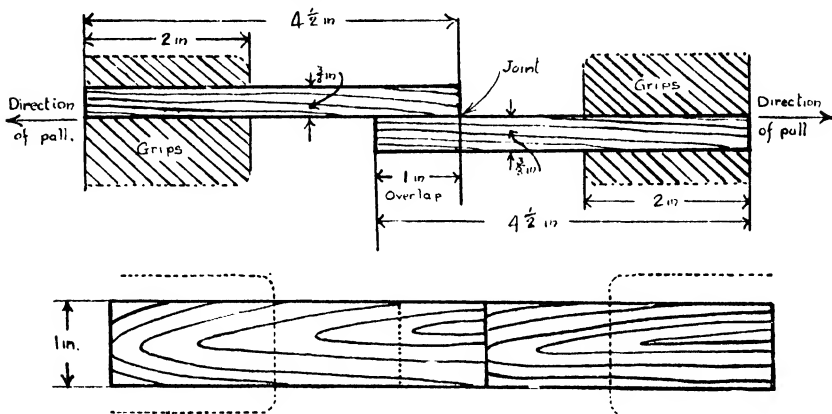
Fig. 16

the plywood should show no appreciable signs of separation or of the formation of blisters. The moisture content should lie between 8 per cent and 18 per cent, when a specimen about 2 in. square is checked in the manner described for spruce, with the exception that in this case the specimen is not dissected for the purpose of testing.

Multi-ply is also subjected to the above tests, except that a compression test is substituted for the tensile test.

For the unstressed class of plywood the adhesive strength test is omitted and greater latitude is allowed with regard to the kinds of timber used in the structure of the boards. Every care should be taken in the storage of plywood : that it is properly stacked and suitably housed. As there are different grades of this material, a very important factor is that the grades are kept entirely separate, and identified so that there is no possible chance of an inferior grade being used in the place of a higher grade plywood.

GLUES

These are of two kinds. The glues which are either in the form of cake or jelly, and which have to be redissolved in water, the cake variety being heated while the jellies are warmed before application, are in one category. The casein cements, or "cold" glues, are of the other kind, and possess a marked advantage over the "hot" glues, as they only require the addition of cold water in correct proportion to make them ready for use.

The method of testing is as follows : Two pieces of wood, preferably of American black walnut, each one inch wide, are glued together with the glue under test. A joint is formed by making a 1 in. overlap of the two pieces; thus the joint is one square inch in area (see Fig. 16). When

tensile tested this joint should stand at least 1,100 lb. per square inch. A similar specimen, after remaining in water for three hours, and drying under normal conditions for half an hour, should stand a pull of at least 1,000 lb. per square inch.

In carrying out this mechanical test it is assumed that the glue has already been tested for melting point, time of setting, etc.

Gluing

The process of gluing, because of its apparent simplicity, is rather prone to be treated carelessly, whereas, for aircraft work, it is highly important.

The rules on the makers' "Card of Instructions" should be strictly adhered to. In application the glued parts should be first clamped in the centre, with additional clamps placed in either side, working outwards to the ends of the parts.   The joints should remain under pressure for at least 24 hours.

Where cake glue is being applied, the room should be free from draughts and maintained at a temperature of 70° F.   That inferior results will be obtained as a result of the glue being chilled at any stage during the process of gluing is fairly obvious.

In the case of casein cements, which are prepared only with the addition of cold water, the relative amounts of water and cement prescribed by the manufacturer should be used.

The containers in which casein cements are supplied should be shaken before use to thoroughly mix the different ingredients, which may have become segregated to a greater or lesser degree during transit from the makers.

FABRIC

For covering aircraft components, linen fabric is used, the weight of which is less than 4 oz. per square yard, with a breaking strength of not less than 90 lb. per square inch width of warp or weft when tested in the following manner.

The method of tensile-

Fig. 17

testing linen fabric is that known as the "wet method," in which the specimens to be tested are soaked in water for half an hour, then removed, and the excess adherent water removed before testing.

The object of "wet" testing is to ensure uniformity of testing conditions, because, if the fabric is tested "dry," the relative humidity of the
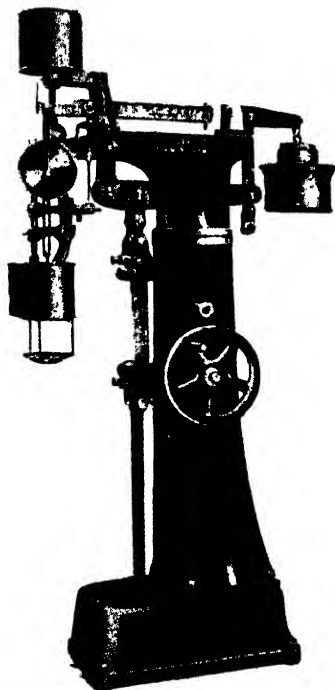
atmosphere may so perceptibly affect the results of the tests as to make them unreliable.

Fig. 17 shows a fabric-testing machine with a specimen under test.

A lighter fabric is used, of course, for glider work.

The testing of fabric to determine absolute conformity with the appropriate specification is to a certain degree of a specialized form, but the ground engineer should himself be able to carry out certain of the checks and tests, or supervise the operations when done by others, as necessity arises.
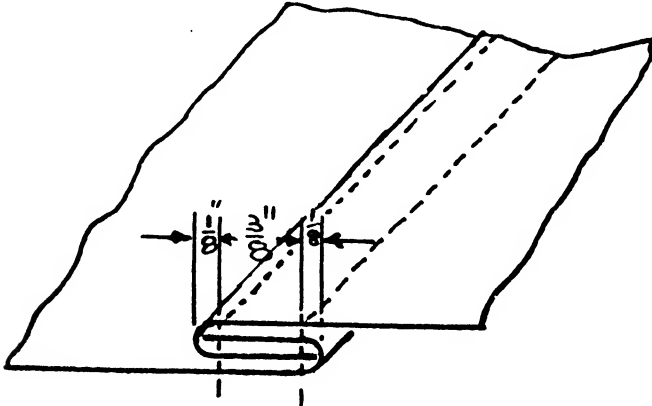
FIG. 18. SECTION OF SEAM FOR SEWING LENGTHS
OF FABRIC TOGETHER

Such instances occur when there is doubt regarding the correlation of a piece of fabric to a certain approved release note, or if the fabric is suspect due to age or indifferent storage conditions. Among the checks possible are the following—

1. Count for ends and picks.
2. Width measurement.
3. Determination of weight per square yard.
4. Testing for strength.
5. Testing for weaving defects, such as snarles, floats, snubs, thin places, etc.

The exact nomenclature in weaving defects is not of prime importance when applying the fabric to the component, but it is important that fabric containing defects which would be detrimental so far as strength and durability are concerned is rejected.

Fabric Covering

Before any attempt is made to cover a component with fabric, a final inspection should be made to see that all the constructional work has been carried out satisfactorily. The fabric should be kept at as near the dope room atmospheric conditions as possible, and under no circumstances left to become damp. The covering, also, should be carried out in a shop which is well suited to the work.

Next, any parts likely to chafe or cut the covering fabric should be locally bound with tape. This binding should be reduced to a minimum, as it absorbs moisture, which is conducive to rotting the timber parts, or corroding the parts of an all-metal component.

FRAYED OR SERRATED EDGED FABRIC

KNOTS

CORDAGE

TAPE

FABRIC

CORDAGE OR STRINGING

FABRIC

RIB
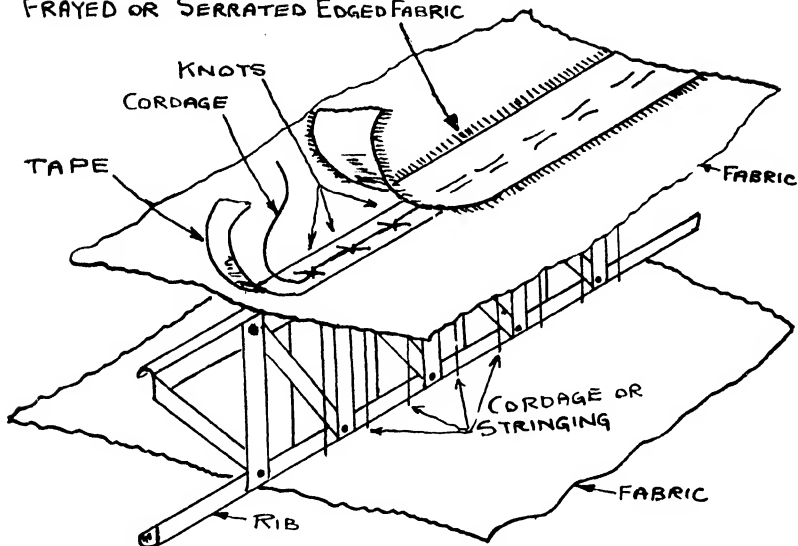
FIG. 19

On wooden components it is usual to glue to the top and bottom of the ribs, which would otherwise make contact with the covering fabric, a layer of Egyptian tape. All "contact" wood parts must have a coat of dope-resisting paint before fabric covering. Metal components should be adequately protected by stove-enamelling or other suitable coating, and it is unnecessary to apply tape to the ribs.

Tape

Loop

Fabric

Stringing Cords

Rib

Special Needle
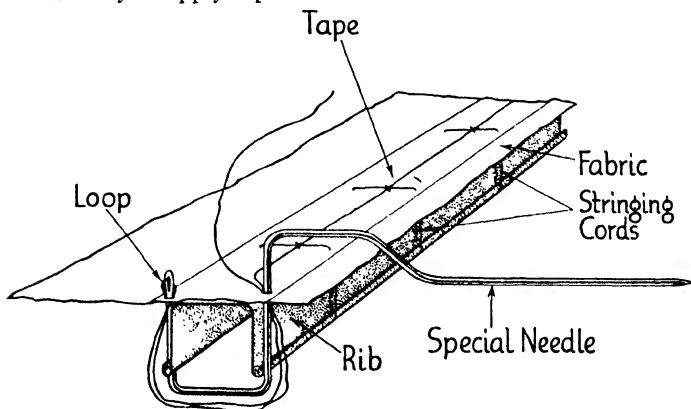
FIG. 19A

The covering fabric is placed on the component with the warp running in a fore-and-aft direction. Occasionally, design calls for the warp to run diagonally across the component. Previous to the application, and if necessary to provide sufficient width athwartships, the lengths of fabric are joined together in the manner shown in Fig. 18, which is known as the

"double balloon seam." With this type of seam, it is important that each of the two rows of sewing passes through each of the four layers of fabric, and this may be checked by means of a light-box.

A light-box has a glass top, and inside is a powerful lamp, so that by passing the seam over the glass top it can be seen whether the sewing is satisfactory or not, because, while so passing, it can be seen through sufficiently.

The fabric is folded over the leading edge of the component, and joined up over the trailing edge. Here, after folding the fabric edges in, they are joined by sewing eight lock-stitches per inch, and double lock-stitching at every 6 in. The stitching thread should be either single 18s or double 40s linen thread to B.S. Specification F.34.

SINGLE KNOTTING
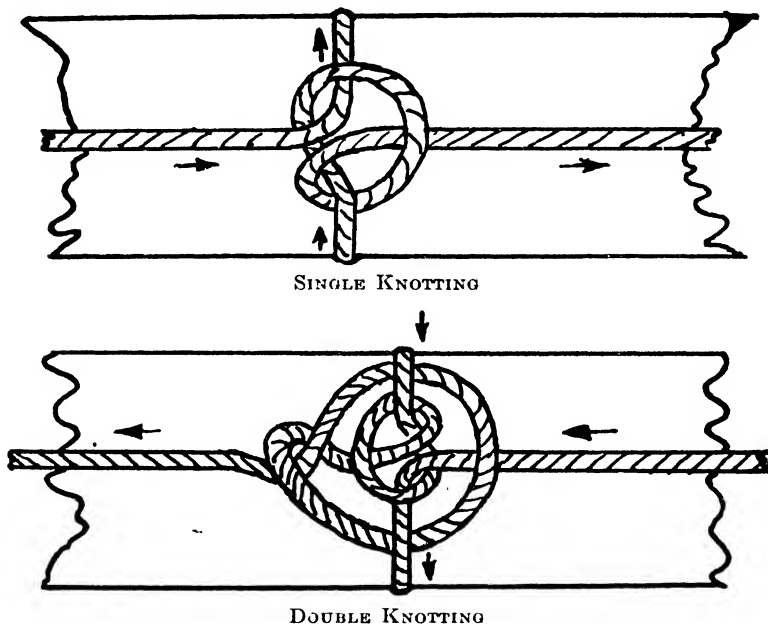
DOUBLE KNOTTING
FIG. 20

During stitching, the fabric should be pulled taut over the component, but not so taut as to bend any members or to twist the component during the doping operation.

The stringing operation is next carried out. This consists of securing the fabric to the framework of the component by means of an approved cordage, in between which and the fabric is interposed a layer of tape as shown in Fig. 19. The cordage is only knotted on the top of the component. The pitch of the knots should be 3 in. where the cord is single knotted (see Fig. 20), and additionally double-knotted at approximately every 18 in. This pitch of 3 in. is reduced to $1\frac{1}{2}$ in. in the case of portions of the component which come in the slipstream of the airscrew when the engine is over 400 h.p. Over this stringing is doped a frayed or serrated edged tape as shown in Fig. 19.

With certain designs of fabric-covered components, especially those of a very deep section, or where the stringing would be fouled by control

wires or rods, it is impossible to use the straight-through stringing passing through the fabric on both sides of the component, as in Fig. 19.

In such cases the cord is passed round the rib boom and knotted externally in the usual manner, for which purpose a C-shaped needle is used.

If the boom section is too large, or of such shape as to render the use of a C-needle impossible, a special needle is used in the following manner—

After forming holes by piercing with the pointed end of the needle, the stringing cord is passed (with the needle eye first) through the tape and fabric on one side of the rib boom, round the rib boom, and out through the fabric and tape on the other side to the position shown in Fig. 19A.

The cord loop at the eye end of the needle is retained for the purposes of knotting, and the needle is withdrawn by sliding the eye over the single cord. The needle is then used for forming the knot, therein utilizing the loop on the other side.

During the process of doping, ripping panels and celluloid windows are added, and the draining holes cut.

After the drying period the component should be inspected to ensure that it is adequately doped in all respects and that no distortion of the component has taken place.

DOPES

For the purpose of tightening, strengthening, and protecting the fabric on aircraft components, dope is applied.

The dopes now used are pigmented, and are either acetate dopes or nitro-dopes. The basis of the former is cellulose acetate, while that of the latter is nitro-cellulose. The question of testing dopes for compliance with the specification is beyond the scope of this work and the work of a ground engineer, and there are no short or abbreviated tests which can be carried out beyond those of the practical application of the dope to fabric, and a careful examination of results. Only approved doping schemes should be employed.

Doping

This process may be carried out under either of two schemes, "Normal" doping or "Anti-chill" doping. Different types of dope are used in the two cases, but whatever scheme is adopted, every attention should be paid to the instructions of the manufacturer of the particular dope in use. The identification symbols of the doping scheme should always be painted on the components.

"Normal" dopes should be applied in a room free from draughts, at a temperature generally not below 70° F., and a relative humidity not exceeding 70 per cent. A suitable hygrometer must be provided to check these conditions.

Although draughts, in the ordinary sense, are to be avoided, the room should be regularly and suitably ventilated with motor-driven fans while doping is proceeding, otherwise the health of the workers may be seriously impaired. Regarding dope-room conditions, there are certain Home Office regulations which must always be observed.

The times for drying, and the methods of applying the dope should be strictly adhered to. The undoped covered component should be placed in the dope-room for a reasonable time before doping is commenced, and in any circumstances doping should not be commenced until the fabric is in a condition consistent with the atmosphere of the dope room.

"Anti-chill" doping schemes were really developed to meet emergency and adverse conditions where there is no alternative to doping at low temperatures and at high humidities, say, at 40° F. and 80 per cent

humidity.   Instances of such cases occur where there is no dope-room available, or when, owing to the large proportions of certain aeroplane components, it is impossible to accommodate them in the dope-room. Even under these circumstances the best available housing should be sought, and doping should not proceed until the atmospheric conditions are within the limits laid down for the particular scheme.

Whatever doping scheme is adopted, it is essential to keep the dope well stirred to ensure thorough mixing; and immediately before pouring from the dope drum to the smaller cans, for shop use, the dope in the drum should be thoroughly shaken or stirred.

The doped component must be finally inspected for—

1. Weight of dope.
2. Uniformity of doping.
3. Smoothness of surface.
4. Uniformity of colour.

The average weight of dope applied should be between 2·5 and 3·5 oz. per square yard.

PAINTS AND VARNISHES

Any material under this heading must always be definitely approved and released to either a B.S. or D.T.D. specification, because the average commercial paint or varnish is unsatisfactory for coating aircraft parts.

The following are among the specifications in general use for protectives for woodwork—

B.S. Specification 3.X.7 .	.	.	Varnish for internal woodwork
B.S. Specification 2.X.17	.	.	Seaplane varnish
D.T.D. Specification 62A	.	.	Pigmented oil varnish
D.T.D. Specification 63 .	.	.	Cellulose enamel

while the following are in general use for metal parts—

D.T.D. Specification 56A	.	.	Stoving enamel
D.T.D. Specification 62A	.	.	Pigmented oil varnish
D.T.D. Specification 63 .	.	.	Cellulose enamel

Beyond the familiar everyday rulings regarding the actual application of these materials, there is little to say. It is essential, however, that the parts, before being brushed or sprayed with the protective coating, should be perfectly dry and free from rust. Rust, even though covered with protective coating, will extend and, in the majority of cases, cause the enamel to flake or peel off.

RUBBER HOSE

Rubber tubing which is suitable for the conveyance of aviation fuel may be in either of two classes. The ordinary class is made of an inner

OUTER WALL

INNER ARMOURING

EXTERNAL ARMOURING

CORE LINING

A TYPICAL SECTION
OF
PETRO-FLEX
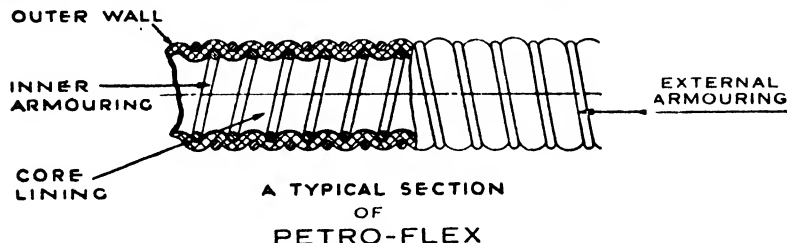
FIG. 21 *(By courtesy of Smith's Aircraft Instruments)*

lining of rubber covered with a number of plies of cotton canvas, which in turn is covered with an outer covering of rubber, the whole being vulcanized together. The other, known as the armoured class, is similar to

the above, but is reinforced by a helix of high tensile steel wire, embedded in the wall of the tubing between two plies of fabric. This tubing is supplied only to definite lengths, as 3 in.; each end is left unarmoured for the purpose of accommodating fixing clips.

The strength of the canvas and quality of the rubber are checked before fabrication into tubing. The amount of free sulphur in the vulcanized rubber compound (excluding the canvas) should not exceed 2 per cent by weight.

To test for permeability to aviation fuel, a sample of the hose 14 in. long is plugged at one end. At the other end is fitted a glass tube 18 in. long, leaving 12 in. of rubber hose between the plug and the glass. It is then filled with fuel to D.T.D. 224 to a level 12 in. above the bottom of

FIG. 22

the glass tube. The glass tube is closed with a cork. By frequent additions the loss of fuel is made good, so that the level never falls more than 3 in. during the first 48 hours. The room temperature should be between 60° and 70° F. The loss of fuel during the third 24 hours shall not exceed 200 milli-litres per sq. ft. of the original internal surface of the hose.

The tubing is tested for resistance to benzol by boiling a 3 in. length for 1 hour in benzol, using a reflux condenser. The apparatus is then allowed to cool down and stand for 24 hours. After removal, $\frac{1}{2}$ in. lengths are cut from each end, and the remaining 2 in. examined. The rubber should show no tendency to separate from the canvas, and should not be friable, i.e. in such a condition that it can readily be disintegrated. The area of the bore when checked by rod gauges shall not differ from the original area by more than 25 per cent for hose above $\frac{1}{4}$ in. internal diameter, or by more than 35 per cent if the internal diameter is $\frac{1}{4}$ in. or less.

The construction of rubber hose for use with hot water is similar to that for use with aviation fuel, but the tests are not so rigorous. The free sulphur of the vulcanized rubber compound (excluding the canvas) should not exceed 1 per cent by weight.

Proprietary brands of flexible tubing have to a large extent displaced the ordinary rubber hose. Such flexible tubing as "Petroflex," "Super-flexit," "Titeflux," and "Avioflexus" are among these brands.

"*Petroflex*," which resists the action of petrol, benzol, and all the hydro-carbon oils, is built up of two walls reinforced internally and externally with coiled wire. Fig. 21 shows the general method of construction. This tubing must not be used for conveying water or steam.

The inner wall or lining, which carries the fluid, consists of a number of layers of natural product specially treated and cemented, and is fitted in tubular form in order to avoid lateral and transverse joints.

The layers of the inner wall vary in number in accordance with the pressure and work to which the tubing is to be applied. The outer wall comprises a specially woven, treated and proofed canvas which is fitted longitudinally, thus eliminating transverse joints.

The internal armouring is practically embedded in the core lining, while the outer wire, although fitting snugly, is proud of the outer casing.

"*Superflexit*," which is impervious to petrol, oil, water, etc., is a reinforced tubing constructed in the following manner—

A tube of cellulose is built on to an inner wire helix so that it lies between the convolutions of the wire and forms the inner lining for conveyance of the liquid. Over this and in turn are appropriately bound fabric strip, sheet rubber, and cotton duck, the latter being proofed to resist petrol and oil. Finally, a wire helix reinforcement is suitably applied to the outside.

"*Titeflex*," which is approved for use on aircraft, consists of a profiled non-ferrous metallic strip spirally wound into a convoluted tube. A double-locked fixed seam is rolled under heavy pressure at the top of each convolution.
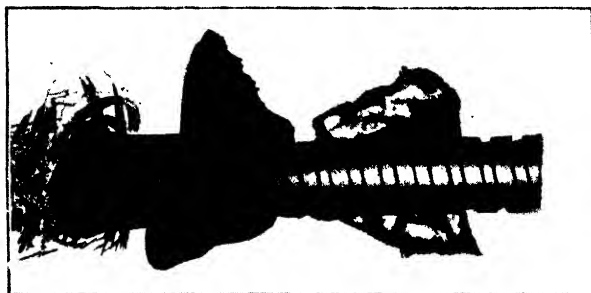
Fig. 22A

This tubing is covered on the outside with two layers of woven casing consisting of fine-gauge tinned wire, the number of strands per plait varying with the size tube. This casing serves to prevent any elongation and twisting under pressure, and as a protection for the tube itself against excessive bending or twisting and general abuse in handling.

The end connections, which are of brass, are soft-soldered to the tube. In the soldering operation it is important that the flux used is non-corrosive. In applying and soldering the end couplings to "Titeflex" metal hose, the makers' instructions and any standard ruling should be strictly observed.

Fig. 22 will give the reader an idea of the method of construction and attachment of the end fittings.

The tube is tested with the end couplings completely fitted, and when bent to the minimum radius laid down for the particular diameter of tube, it shall show no signs of leakage when submerged in water and subjected to an internal air pressure of 100 lb. per square inch.

It should be understood that the test pressure of 100 lb. per square inch mentioned above is normally adopted as being sufficient to cover all normal requirements, but pressures up to 2,000 lb. per square inch have been withstood by this class of tubing.

NOTE: Titeflex is entirely metallic, but has been added to this section as it falls under the heading of flexible tubing.

"*Avioflexus*" *Tubing* is applied to both aircraft fuel and oil systems. It is built up from an inner flexible tube of aluminium or brass, according to requirements, directly covered with cellulosic sheet which is bound with twine between the corrugations. Superimposed upon this cellulosic covering is a rubber tube which is vulcanized in position. The whole is then protected and reinforced by a strong braiding consisting of tinned iron wire. See Fig. 22A.

After the end connections have been fitted, each length of tubing is filled with paraffin and subjected to pressure for at least one hour, during which period there should be no evidence of leakage or failure. For tubes not exceeding ¾ in. diameter bore, 100 lb. per sq. in. pressure is applied, and for tubes of greater diameter, 75 lb. per sq. inch.

These types of tubing are all fitted with special designs of end fittings forming the connecting unions, which also provide a means of electrically bonding each tube from end to 'end. The tubing is tested for pressure, flexibility, permeability, and resistance to heat, the tests varying to some extent in accordance with the class in which the type of tubing falls.

The tubes are usually supplied by the makers to the lengths ordered, and with the end fittings properly attached, but should it become necessary to change or detach the end fittings, the particular instructions laid down regarding the method of attachment of these fittings should be strictly adhered to, as indifferent fitting will lead to the possibility of leakage.

RUBBER SHOCK ABSORBER CORDS

This cord consists of a multiple number of rubber threads which have been tightly bound in two layers of cotton braid while in a very outstretched condition. It is applied for taking the shock load in landing on certain types of aircraft, by being suitably connected on the undercarriage and on the tail skid.

As the useful life of rubber is comparatively short, and it is a matter of some difficulty to determine visually whether it should be replaced or not, it is important to know the approximate date of manufacture, and the specification allows for this by having specially coloured cottons interwoven with the braiding. The particular colours for each year are—

1933	.	.	.	Green	1937	.	.	.	White
1934	.	.	.	Heliotrope	1938	.	.	.	Green
1935	.	.	.	Yellow	1939	.	.	.	Heliotrope
1936	.	.	.	Blue					

and the number of cottons to be included are—

Cord made between—

1st January and 31st March inclusive	.	.	.	1
1st April and 30th June inclusive	.	.	.	2
1st July and 30th September inclusive	.	.	.	3
1st October and 31st December inclusive	.	.	.	4

The mechanical properties of the cords are given in Table II—

TABLE II

Size of Cord	Load in lb. to give 10 per cent Extension	Load in lb. to give 100 per cent Extension		Load in lb. in Addition to the Actual Load Producing 100 per cent Extension to give an Extension of 105 per cent of the Initial Length of the Finished Cord
		Finished Cord	With Outer Braiding Removed	
In.	Min.	Min.	Max.	Max.
⅜	15	70	90	Shall be not less than 45 per cent or more than 55 per cent of the actual load obtained on each Finished Cord	15
½	30	130	155		25
⅝	42	200	240		40

After removal of the loads in Table II, restitution shall be prompt and complete. There are certain variations in the above test results for different temperatures, and for these the particular specification makes graduated allowances.

LEATHER

The use of this material for anything beyond the manufacture of straps, etc., for fixing equipment, should be discouraged.

It should never be used under pipe clips or at all permanently in direct contact with structural metal parts, as it assists corrosion to a very marked degree. It may be used providing that some such material as "Langite" or "Systoflex" is placed between it and the metal.

CHAPTER II

METALLIC MATERIALS

THE metals under this heading which are used on aircraft are iron, steel, aluminium, including its alloys, such as duralumin, and the comb:nation of duralumin and aluminium known as alclad; copper, and the various brasses and bronzes.

Iron

The almost exclusive uses of this metal, apart from its use in steel manufacture, are for welding and as a wire for locking purposes on turn-buckles, etc.

It is applied for the former purpose owing to its adaptability as a filling medium in welded joints. The essential point in its inspection is that it shall comply with the appropriate specification, which calls for a content of ·1 per cent of carbon, and for the absence of foaming and spluttering during welding.

Steel

This metal is used to many and varied specifications, but generally the steels may be classed under such main headings as mild, high tensile, stainless, and steels suitable for case-hardening.

The mild steels are low or medium in carbon content, with an ultimate tensile strength between 25 and 40 tons per square inch. Such steels are used in the form of bar, sheet, tube, and forgings or stampings.

Those of the high tensile variety are generally alloy steels, which possess such contents as nickel, chromium, tungsten, manganese, molybdenum, etc., with always a certain percentage of carbon. The range of tensile strengths, which varies with the proportion of the various elements and with the particular heat treatment applied, fall between 45 and 100 tons per square inch.

High tensile steels are used in the form of bar, sheet, strip and tube, castings, forgings, and stampings.

Stainless or Rustless Steels are alloy steels with a comparatively high percentage of chromium, which gives them the quality of being rustless. It might be pointed out at this stage that such steels will not entirely resist the intensive action of the chlorides of the sea and sea air, but they go a very long way towards this object. Although it is not always possible, the resistance to rust is assisted by keeping the steel clean and minimizing any prolonged action of corrosive deposits.

Mild Steel Sheet

In the manufacture of wiring plates and built-up fittings which have to be bent or welded, hot rolled mild steel to B.S. Specification 3.S.3. is extensively used. The chemical composition of this steel is as follows—

Carbon	·2 to ·25 per cent
Silicon not more than	·3 per cent
Manganese not more than	·6 per cent
Sulphur not more than	·05 per cent
Phosphorus not more than	·05 per cent

The sheets and strips after rolling are re-heated at a uniform temperature of not less than 500° C. and allowed to cool freely in still air.

The material should conform to the following mechanical tests—

(a) *Tensile Test*

0·1 per cent proof stress (all thicknesses)
Not less than 16 tons per sq. in.

Ultimate tensile stress (all thicknesses)
Not less than 28 tons per sq. in.

Elongation (for thicknesses greater than 12 S.W.G.)
Not less than 20 per cent.

For purposes of these tests, the tensile test samples are cut from sheets so that the longitudinal axis of the test piece is at right angles to the
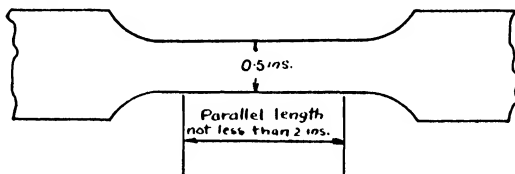
FIG. 23

direction of final rolling, and in the case of strip material parallel with the length of the strip.

The elongation is measured on a gauge length of 2 in. and a width of 0·5 in. (see Fig. 23).

(b) *Single-bend Test* (12 S.W.G. and thinner).

The test pieces must withstand, without cracking, being bent over a radius equal to half the nominal thickness of the sheet or strip.

(c) *Reverse-bend Test* (12 S.W.G. and thinner).

The test pieces are fixed in a vice between formers, the inner edges of which have a radius equal to three times the nominal thickness of the sheet or strip. The projecting length of the test piece is then bent at right angles to the fixed end, first to one side and then to the other, until the test piece breaks. Each test piece must withstand without cracking three bends through 180°, the first bend through 90° not being counted.

(d) Each sheet and strip shall be bent at the corner through 180° over a radius equal to half the nominal thickness of the material, without cracking.

Mild Steel Bars

A steel which is extensively employed in the manufacture of low tensile bolts and nuts is that complying with B.S. Specification 3.S.1. It has a chemical composition of—

Carbon between	.	.	.	0·15 and 0·40 per cent
Silicon not more than	.	.	.	0·30 per cent
Manganese between	.	.	.	0·50 and 0·90 per cent
Sulphur not more than	.	.	.	0·05 per cent
Phosphorus not more than	.	.	.	0·05 per cent

The material should be free from the defects which are mentioned under "Defects" described in this section.

The margins of manufacture are tabulated in the specification, and the finished bars are delivered in the cold rolled, drawn, or machined condition.

At the option of the manufacturer, the bars may be reheated at a

temperature not exceeding 620° C. before or after cold working. The mechanical properties of the steel are as follows—

Maximum stress . . .	between 35 and 45 tons per sq. in.
Elongation . . .	not less than 15 per cent
Reduction of area . .	not less than 40 per cent
Izod value	not less than—
	40 ft.-lb. for bars up to and including ¾ in. diameter (or width across flats)
	25 ft.-lb. for bars over ¾ in. and up to 1½ in. diameter (or width across flats)
	20 ft.-lb. for bars over 1½ in. diameter (or width across flats)

Steel Tubes

Apart from the chemical composition of steel tubes, the important factors in the acceptance of tubing are methods of manufacture, heat treatment, mechanical tests, freedom from defects, dimensions, and straightness.

Taking, for example, the tubing called for in B.S. Specification 2.T.1, the chemical composition of which is—

Carbon not more than	·4 per cent
Silicon ,, ,, ...	·35 ,,
Manganese ,, ., ...	1·75 ,,
Sulphur ,, ., ...	·05 ,,
Phosphorus ,. ,, ...	·05 ,,

Such tubing is extensively used in the formation of struts for the structural parts of all-metal aircraft. The tubes are seamless and cold drawn, which means that they are solid drawn to their finished dimensions without heating during the process of drawing. This cold working improves the tensile qualities of the material without impairing the other qualities. The tubes are then "blued" by being heated to a temperature between 350° C. and 480° C. and cooling in still air.

The defects for which steel tubes are examined are seams, draw marks or scores, which may be caused by scale or dirt between the tubes and the dies, and such defects as are sometimes found in bar steels.

The outside diameter and the gauge or thickness are the only dimensions required for the description of the cross-section of a tube unless that tube happens to be specially tapered, streamline in form, or otherwise differently shaped at various intervals in its length. This stated diameter is taken as the nominal diameter, and limits are tabulated in the specification for each size of tube. Likewise limits controlling the allowable variations from the mean thickness or gauge of the material are stated.

The observance of the ruling regarding these limits is imperative, as the tubing often has to be fitted by socketing, or used as liners in other parts or larger tubes of the aircraft structure, so that satisfactory functioning and efficiency of assemblies affected depend on this factor.

Tubes must always be free from kinks or any local bending. and in any selected length of 20 in. the bow must not exceed 1·600th of the length.

The maximum tensile stress of tubing to 2.T.1 Specification is not less than 35 tons per square inch. When the full section of the tube is used for this test, the stress values are calculated on the nominal thickness of the tube, but if a strip of the material is used the actual dimensions of the test piece are taken for calculating the stress.

The flattening or bending test is carried out by placing a ring of the material between flat faces as in Fig. 24, the faces being struck six to twelve times with a hammer until the distance between the faces is equal to three times the nominal thickness of the tube. This test must be withstood without any sign of cracking.

A proof bend test is carried out on each tube, being applied to alternate ends of the tubes of each batch heat-treated together. A special machine
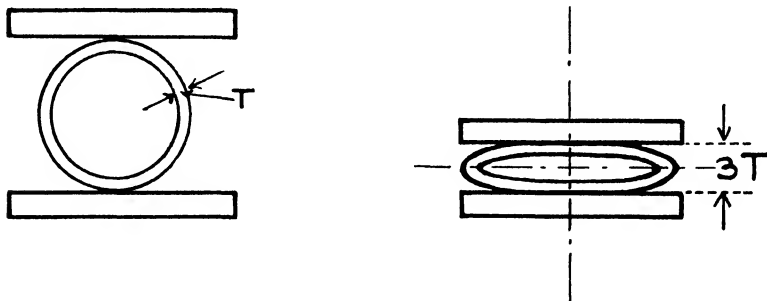
Fig. 24

is employed for this test, and is designed to avoid injuring the tubes. Fig. 25 shows diagrammatically how the load is applied. The tube is held down at *A* and supported at *C* while the proof load is applied at *B*. The deflection δ is measured at a predescribed point *E*.

Upon application of the load, the deflection registered should not exceed by more than 5 per cent the calculated deflection for a tube of
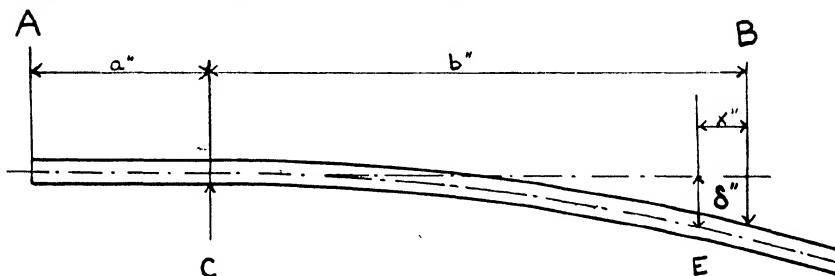
Fig. 25

similar dimensions and loading, by using a bending stress of 30 tons per square inch and a value for Young's Modulus of 13,300 tons per square inch.

The full details, with a complete description of the testing apparatus, are given in the specification.

Copper

Copper is used in its pure state in the form of tubing and of wire for electrical purposes. It is also used with other metallic elements to form such alloys as duralumin, brass, and bronze.

The chemical composition of copper tubes employed for petrol and oil systems and for general purposes on aircraft is copper not less than

99·2 per cent, arsenic between ·3 and ·5 per cent, while the impurities must not exceed ·05 per cent of antimony and ·01 per cent of bismuth.

The tubes are solid drawn, and must be free from defects. Tubes up to and including 1 in. outside diameter are supplied by the maker in the fully softened condition, which softening is carried out by heating uniformly to a temperature between 600° C. and 700° C. In this softened condition they may be worked for fitment in aircraft without further heating. Tubes of over 1 in. outside diameter are supplied in the half-hard condition, and are heated for bending and working, after which they should be carefully annealed at the above temperature. The special limits of diameter and thickness which are specified should be strictly adhered to.

The tubes are subjected to the following tests:

A *Tensile Test* is carried out on a flattened strip cut from the tube, and must give a maximum stress between 14 and 17 tons per square inch for the softened tube, and not more than 20 tons per square inch for the half-hard tubes.

The *Flattening Test* is carried out on a test piece not less than 2 in. long, and this must stand flattening until the interior surfaces meet without any evidence of cracking.

Drifting Test. Tubes up to and including ½ in. outside diameter shall be expanded at the ends by drifting, to an angle of 30°, or until the outside diameter of the drifted end is not less than 50 per cent greater than the original diameter, while tubes above ½ in. outside diameter shall be drifted until the outside diameter is not less than 25 per cent greater than the original diameter of the tube. In each of these cases there shall be no signs of cracking, otherwise the tube should be rejected.

Bore Test. Each tube shall be internally cleared by means of steam or compressed air. Tubes of less than ⅜ in. outside diameter shall be tested by passing air at low pressure through the tube, and while the outlet end of the tube is immersed in water, shall emit a continuous flow of air. For tubes of ⅜ in. diameter and over, a visual examination by the inspector is sufficient.

The Hydraulic Test. Every tube must be subjected to a hydraulic test pressure of 250 lb. per square inch without showing any signs of failure. High pressure copper tubing is subjected to a hydraulic pressure of 6,000 lb. per square inch, under which test there must be no signs of failure.

Flexible Steel Cable

The wire from which this cable is made is lower in phosphorus and sulphur contents than other aircraft steels, which, of course, increases its flexible property.

All wire is coated by hot galvanizing before being drawn to its final size, as a measure against corrosion. In addition, the wire for the manufacturing of straining cords is to be evenly tinned. Previously to being labelled as ready for the rope or cable manufacture, each length of the wire is tested in tension and torsion as laid down in the specification. The numbers of wires and strands employed in the various strengths of the cables are tabulated in the specification.

Each length of cable is checked for missing wires, slack strands, crossed wires, crossed strands, kinking, and other irregularities which will produce inefficiency in the cable.

Finally the cable is tested and inspected for diameter, weight, construction, uniformity of lay, and breaking strength. At the completion of these tests each cable must be wound in an approved manner on a reel

with a barrel having a diameter of not less than 30 times the diameter of the rope in the case of extra-flexible ropes, and not less than 40 times the diameter in the case of straining cords.

It is also imperative that each coil of rope bears a tally marked with the specification number, an identification mark, and an indication regarding the method of coating—that is, galvanized and tinned, or galvanized only—the test report number, and the stamp of the inspector.

Brasses and Bronzes

Brasses in the form of bar are employed in the manufacture of nuts, bolts, unions, nipples, etc., while elbows, three- and four-pieces for pipe connecting are made from brass castings. For certain bearings and parts requiring hard-wearing properties phosphor bronze and gunmetal are extensively employed.

Brass sheets are occasionally called for in the design of tank shells, but apart from this brass sheet is only used for such parts as securing clips and for lightly stressed work.

The chemical composition of brass bars suitable for brazing or silver-soldering is—

Copper between 78 and 82 per cent.
Total impurities not more than 1·25 per cent, of which lead must not exceed 1 per cent.
Zinc, the remainder.

The maximum tensile stress stated in the specification is not less than 20 tons per square inch. The tensile test piece for this and the brasses described in the following paragraphs has a gauge length of four times the square root of the sectional area of the specimen. A simple bend test is carried out by bending the specimen over a radius equal to the diameter of the specimen, through an angle of 120°, which test must be withstood without cracking. For bars over $1\frac{1}{2}$ in. diameter, the bend specimen is turned eccentrically to the $1\frac{1}{2}$ in. diameter, so that it includes the skin at one side of the bar, and the specimen bent with the skin side in tension.

For high speed screwing and turning, a brass bar of the following composition is used—

Copper, not less than 55 per cent.
Lead, between 1·5 and 3 per cent.
Total impurities, not more than 1·75 per cent.
Zinc, the remainder.

It has a tensile strength of not less than 25 tons. No bend test is called for.

High tensile brass consists of—

Copper, between 54 and 62 per cent.
Total metals other than copper and zinc, not more than 7 per cent.
Zinc, the remainder.

The maximum tensile stress is not less than 35 tons per square inch for bars under 1 in. diameter, and 30 tons per square inch for bars over $1\frac{1}{2}$ in. diameter.

Referring generally to the above brasses, for the purposes of comparison, a Brinell test is carried out on a flat, filed on the tensile-tested bar, and then similarly on otherwise untested bars. It is possible, by comparing the hardness numbers with those obtained with the original bar, to decide that the material is homogeneous.

On all the above brasses, various methods of manufacture are permissible, including extruding, rolling, and drawing. The bars must be free from surface and other defects, such as piping. All bars approved are stamped with the specification number, the inspector's identification mark, and the manufacturer's trade-mark or symbol.

Phosphor-bronze is an alloy consisting of 10 to 13 per cent tin, ·5 to 1 per cent phosphorus, the remainder being copper, with an allowance of not more than ·50 per cent for total impurities.

MONEL METAL

This is a high Nickel Copper alloy from which is produced both sheets and bars. It is distinct in its resistance to all forms of corrosion. The Chemical composition is as follows—

Nickel not less than	64·0 per cent
Nickel not more than	70·0 per cent
Manganese not less than	0·3 per cent
Manganese not more than	2·0 per cent
Iron not more than	2·5 per cent
Total Impurities not more than . . .	0·3 per cent
Copper	the remainder

It is delivered in the form of sheet in the annealed condition, with the following mechanical properties—

(a) Maximum stress—not less than 30 tons per square inch.

Note. The 0·1 per cent Proof Stress is not less than 7 tons/sq. in.

(b) Close Bend Test: The test pieces must withstand without cracking being bent through 180° and closed down flat.

(c) Bend Test on Sheets: The actual sheet is tested on one corner and must withstand without cracking being bent through 180° and closed down flat.

In Bar form in the annealed condition, and suitable for cold bending, the properties are as follows—

Maximum Stress not less than . . .	30 tons/sq. in.
Elongation not less than	35 per cent

Brinell Tests. A Brinell test is carried out on 10 per cent of the bars in each parcel, and the hardness number compared with the Brinell test number of the Tensile specimen, in order to determine that the material of the whole consignment is homogeneous.

Bars in the rolled, drawn and tempered condition have the following properties—

0·1 per cent Proof Stress not less than	30 tons per square inch
Maximum Stress not less than . .	45 tons per square inch
Elongation not less than . . .	18 per cent.

This material is also suitable for forgings and stampings.

INCONEL

The use of this alloy is steadily increasing in its application to aircraft. The reason for this is that it contains approximately 80 per cent nickel, 13 per cent chromium, and the remainder iron, and such an alloy as this has a high resistance to corrosion and heat oxidization.

It is hardened by cold working, and not by heating. By this method its strength can be increased from 36 tons per sq. in. to approximately 85 tons per sq. in. It may be soft-soldered, silver-soldered, brazed, or welded by the oxy-acetylene or metallic arc processes.

With its special properties, it is not surprising that its use is increasing

in the manufacture of exhaust pipes and manifolds and cabin heaters, where it is applied also in tubular form.

The mechanical properties are as follows—

	Tensile Strength	Yield-point	Elongation
	Tons/sq. in.	Tons/sq. in.	Per cent.
Sheet and Strip			
Annealed	35–40	13–15	45–55
Rod			
Annealed	35–40	13–15	45–55
Cold drawn	45–50	35–40	20–30
Wire			
Annealed	35–40	13–15	45–55
Spring temper	78–85	—	—

Inconel is annealed by heating to a temperature between 1,000° and 1,050° C., soaking for only 5 minutes at this temperature and allowing to cool in air. The rate of cooling is not important. The furnace should be electric, or one fired with gas or a high-grade oil. Coal or coke furnaces are unsuitable. The furnace should be brought to the required temperature before the articles are put in.

If formed parts are to be assembled by welding, it is desirable that after forming they should be annealed in the manner described above, before welding is commenced.

IDENTIFICATION OF MATERIALS

All aircraft materials must be properly tested, released, and correlated with their particular release notes, and the care and attention thus demanded would not have the desired result if, when any such material reached an aircraft maker or repairer, the correlation was immediately lost and its significance ignored.

In this connection it is absolutely imperative that when, say, a high tensile steel part is being fitted to an aircraft under any circumstances whatsoever, there shall exist satisfactory evidence that the fitting is made from material to the requisite specification, and that it is not by mistake made from mild steel having approximately half the strength required for the fitting. It is therefore essential that at all places where aircraft are manufactured or repaired, an adequately bonded stores should be maintained where materials may be kept for these specific purposes.

Only approved aircraft materials should be kept in this store, so that there is no possibility of non-aeronautical materials being mixed therewith, and in addition, only authorized personnel should be allowed access thereto.

All bars, tubes, sheets, castings, etc., should be marked or symbolized so as to identify them with the particular covering release note. In addition, if the stores contains large stocks of various aircraft materials, it is usual to employ a "colour scheme" which will facilitate identification of a material with the specification, and avoid the many possibilities of mixing the different materials after issue to the workshops. This "colour scheme" includes painting each bar, tube, etc., with a colour, or two or three different colours, preferably from end to end, so that if a short length is cut from a

bar of material, the specification for that material will be definitely known for as long a time as possible after the material has reached the workshop.

A series of different combinations of colours for each material is listed in the Inspection Leaflet 122, and is recommended for general adoption.

In addition, it is wise, when cutting short lengths of material for use or for issue to the workshops, to cut from the end opposite to the one carrying the manufacturers' identification marks and inspection stamp, so that these records may be retained for as long as possible. Where stores indents and job cards are used, such material identification references
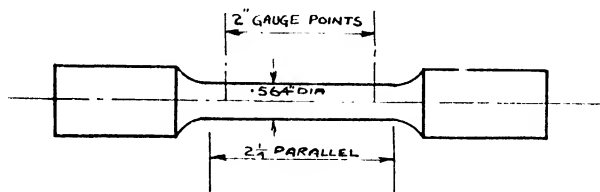
FIG. 26

should be quoted thereon as will serve to identify the material for as long a period as possible.

TESTING METALLIC MATERIALS

One of the most essential points in testing materials is that the piece or pieces selected must be truly representative of the bulk.

In testing bar material, a typical specification lays down that the bars must be from the same cast and grouped in parcels of not more than 100. Thus assured, the inspector selects one from each parcel, which is machined and tested to the requirements of the specification. If this sample complies with the necessary requirements, the whole parcel may be approved and stamped.

In the case of certain steels, dependent upon the specification, a specimen is taken as above, and in addition to the tensile test is Brinell tested. Assuming that the tensile test results and the Brinell figure are satisfactory, the remainder of the bars are then Brinell tested, and if the figures obtained are consistent with that obtained for the original specimen, it indicates that the bars are homogeneous and satisfactory in this respect.

To illustrate this principle still further, the instance of castings may be taken. If castings are large, one test sample is cast to represent each casting. If castings are so large as to require more than one charge, and the charges are not mixed prior to casting, a test sample is cast to represent each charge.

With small castings a test piece is cast to represent a certain weight of the metal poured, say, for every 100 lb.

The specifications for steels lay down that the material shall conform to a certain chemical analysis, and have particular mechanical properties after being cold-rolled or heat-treated, etc. It is stipulated that the complete analysis of the cast from which the bars are produced shall, on request, be supplied to the inspector. The determination of the chemical composition is the work of a specialist in chemistry and not that of a ground engineer.

Further, while it is not essential that a ground engineer in this category shall himself be able to carry out the mechanical tests called for in the specification, it is important that he should possess sufficient knowledge of mechanical testing to enable him to deal in a technical manner with the

results stated in the test reports, and satisfy himself from these reports that the material conforms to the requisite specification in all respects.

The usual mechanical tests called for in a specification for steel bar are those of tensile, nicked fracture, izod or impact, and hardness tests.

The tensile test consists of pulling and breaking a prepared length of the steel in a suitable testing machine, and during the test, and afterwards, determining values representing certain of the mechanical properties of the steel. A typically prepared length, and one of those adopted by the British Standards Institution, is shown in Fig. 26. Here it should be noted that the portion of the specimen considered for calculation purposes is that between the marked gauge points. The diameter of ·564 in. is taken

REDUCED AREA.
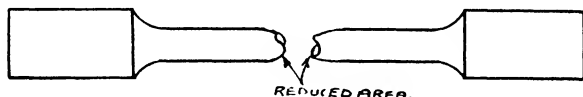
FIG. 27

for convenience, because the calculated area of a bar of this diameter is exactly ·25 square inches. The broken pieces of the specimen after the test are shown in Fig. 27.

The ultimate tensile stress in tons per square inch is calculated by dividing the maximum load applied in breaking the specimen by the original sectional area in square inches. The yield stress is similarly calculated by dividing the load at which the material first commences to draw out or extend, with little or no increase to the load, by the original sectional area of the specimen.

The reduction of area per cent is equal to $\dfrac{A - a}{A} \times 100$, where $a =$ the area in square inches at the break, and $A =$ the original area of the specimen in the same units. The elongation per cent is equal to $\dfrac{1 - L}{L} \times 100$ where $1 =$ the length between the gauge points when the broken pieces are pieced together, and $L =$ the original length between the gauge points as shown in Fig. 26.

It is possible to show graphically the relationship between the various extensions and the different loads obtained as the result of any tensile test. A typical curve for a mild steel specimen is shown in Fig. 28.

This curve may be produced by plotting the actual figures obtained during the test, or directly while testing, if the testing machine is fitted with the recording apparatus.

In examining this curve, it will be seen that when the load is first applied, very little change takes place in the length of the specimen and up to the point marked B, if the load is removed, the specimen will return to its original length, and in so doing obeys what is known as "Hooke's Law." The stress at point B is known as the Elastic Limit, or the point at which Hooke's Law breaks down, and the specimen begins to take on a permanent set, or, in other words, just beyond this point the material becomes over-strained.

As further loading is applied, a point C is reached where the material stretches or extends considerably with no or very little increase to the load. This point is known as the Yield Point, and the stress at this point as the Yield Stress.

After this, it will be noted that the material extends more or less

proportionately as the load increases, until the ultimate stress is reached at the point D. Between the points D and E the stress appears to decrease. This actually is not the case, because the area of the specimen has become locally reduced, and therefore less load is required to maintain the necessary tension. Thus it will be seen that although the apparent stress at which the material breaks is recorded at E, the actual ultimate stress is recorded at point D.

STRESS - STRAIN DIAGRAM.
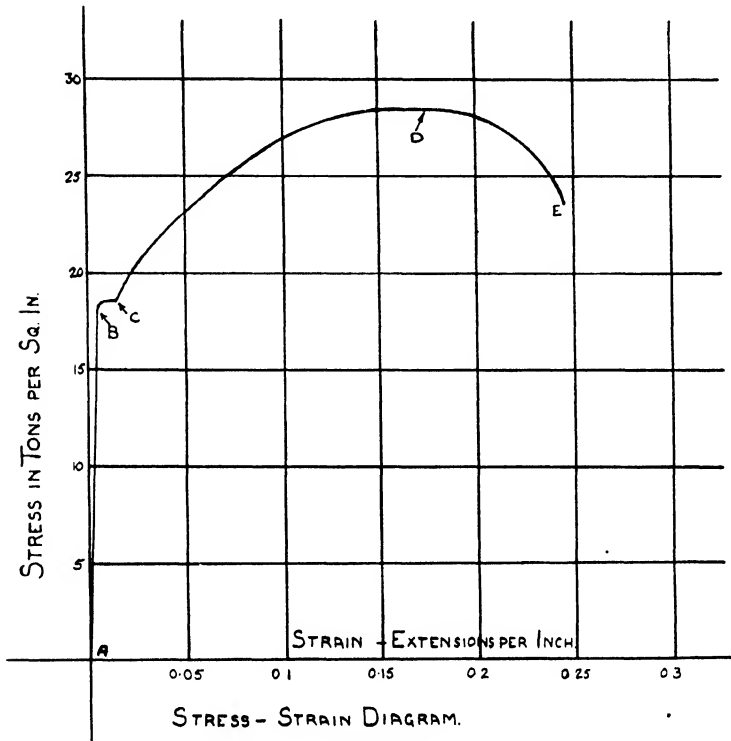
FIG. 28

Fig. 28A illustrates an Avery Universal Testing machine. It is of the vertical single-lever type, which is capable of carrying out Tensile, Compression, Bending, Shearing and Torsion tests. The main parts of the machine are as follows—

$A.$ Specimen under tensile test.
$B.$ Shackles carrying the gripping wedges securing the specimen.
$C.$ Steelyard weighing lever.
$D.$ Steelyard graduated in lbs. etc., indicating the load applied to the specimen.
$E.$ Travelling poise weight with vernier scale attached.
$F.$ Handwheel for moving poise weight along steelyard lever through gearing and screw G.
$H.$ Column carrying fulcrum on which is balanced the steelyard lever. A diagrammatic view of the knife edges is shown in Fig. 28B.
$J.$ Variable speed motor for applying strain to the specimen through gearing at K.
$L.$ Lever operating motor.

M.   Column at the top of which are stops for steadying steelyard lever.
N.   Pointer indicating neutrally poised position of steelyard lever.
O.   Autographic load-extension recorder which is an optional fitment.
P.   Additional attachments for compression, bending tests, etc.

Assuming the tensile specimen already gripped in position for testing as shown in Fig. 28A, operations are commenced by applying strain with the motor and simultaneously, if necessary, moving the poise weight from
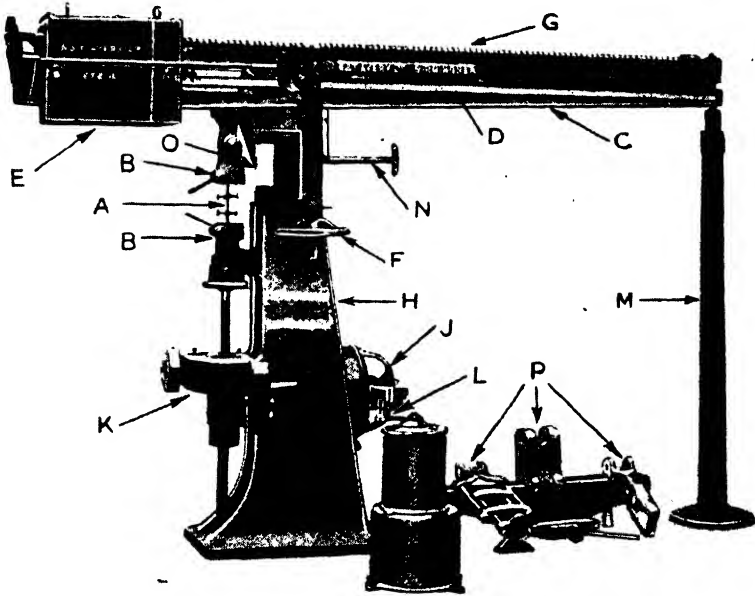
FIG. 28A

its zero position along the steelyard lever, by means of handwheel and lever movements, which are so made that the steelyard lever remains poised approximately midway between the stops at the top of the column *M* until the specimen is broken. This condition is best obtained by the operator watching the movement of the pointer indicating the neutrally poised position.

The lever may bear on either of the stops at different periods of the test, but when it does so, the poised position is again obtained by use of the motor or poise weight handwheel, i.e. applying more strain to the test piece when the steelyard is on the bottom stop, or by moving the poise weight, i.e. increasing the stress in the test piece when the steelyard is on the top stop.

The poise weight may be divided into two parts, the smaller portion of which, in conjunction with a second graduated scale on the steelyard,

will give readings from zero up to 2 tons. Thus finer sub-divisions are obtained for low capacity tests.

It should be noted that when testing such materials as mild steel, that is, if a load extension diagram is being recorded, it will be necessary for the poise weight to travel backwards towards zero position after the maximum stress has been reached. See Stress-strain diagram in Fig. 28 between the points D and E.

Nicked Fracture Test

A representative specimen is nicked or sawn, leaving the area of the part to be fractured at least equal to half the sectional area. The specimen
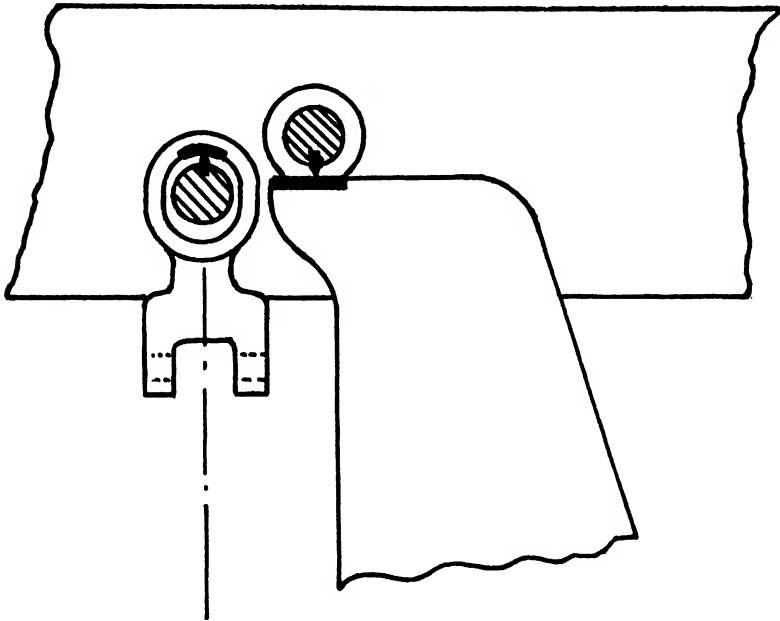
FIG. 28B

when broken by a minimum number of hammer blows shall show a fracture of the type described in the specification.

Hardness Testing

In the various B.S. and D.T.D. Specifications, a Brinell (or other approved) Hardness test is called for. In addition to the Brinell Hardness Tester, the Vickers Diamond, Rockwell, and Firth Hardometer Testing machines have been approved for use.

1. BRINELL TESTER

On this machine an impression is made on the specimen under test with a 10 mm. diameter ball, the load being applied by means of oil pressure. The total load on the ball is equal to 3,000 kg., and is maintained for not less than 15 sec. The diameter of the impression is then measured and the equivalent hardness number is taken from a schedule of factors laid down for the test. There is generally a relationship between the

Brinell hardness number and the equivalent tensile stress for the purpose of steels only. As an example, supposing a heat-treated alloy steel has a Brinell number of 300. The equivalent tensile stress is equal to $300 \times \cdot 22 = 66$ tons per square inch. There are other factors for the particular kinds of steel involved. In the case of lighter gauge materials, a different diameter of ball should be used, and a lighter load applied, but it should be remembered that Brinell impressions should never be made where the mass of the material is not sufficiently adequate to stand the load without damage to the part being tested.

2. VICKERS DIAMOND HARDNESS TESTING MACHINE

This machine is used for testing all kinds of metallic materials, but is particularly suitable for the testing of thin steel tubing, strip, sheet, and case-hardened steels. The standard loading is 30 kg., which may be reduced to 5 kg. for thin materials, and provided the material under test is homogeneous, the value of the hardness numeral obtained is not affected by the change of loading.

3. ROCKWELL MACHINE

The load in this case may be applied either through a small ball or a conical diamond. The hardness values obtained are only correlated with the tensile properties of the material from comparative tables compiled from previous observed data for each type of material. The hardness numbers cannot normally be correlated with the tensile stress as in the case of a Brinell machine.

As an instance of its application, supposing a number of sections or parts are to be rolled from a particular coil of strip and afterwards heat-treated. Before commencing operations a specimen is cut from the strip and heat-treated in the manner prescribed for the sections or parts. This specimen is then fully tested to the requisite specification and the Rockwell figure determined.

Assuming that the specimen complies with the specification, and that the Rockwell number is 70, then if the Rockwell numbers of the sections or parts after heat-treatment come within $+$ 2 of this number, it is a reasonable assurance that the heat-treatment of the parts has been carried out correctly, and that their tensile strengths are correct.

4. FIRTH HARDOMETER

This machine is similar in principle to the Brinell machine, with the exception that the load is applied through the compression of a spiral spring operated by a hand-wheel. The loading used is either a 120 kg. or a 30 kg. spring box. For the harder materials a pyramidal indenter is provided in addition to the hardened steel ball, the numbers obtained with the diamond and steel ball respectively being comparable as shown in the table supplied with the instrument.

Impact Testing

When this method of testing was first applied to aircraft materials, the results obtained were considered to give an indication of the toughness of the material, or its power to resist shock. Instances occurred where bolts, when subjected to working conditions, snapped off just under the head, which bolts, when tensile tested, were found to pass this particular test satisfactorily. This confirmed the necessity for the Izod Impact Test. The test has since proved to be of greater value, as it has been found to

reveal indications of incorrect heat-treatments and unsatisfactory chemical composition of the various materials. If, for instance, the impact value of a steel is low, it may indicate that the steel has been incorrectly heat-treated, but if there is no doubt regarding the heat-treatment, the question of analysis might be investigated.

The type of machine most commonly employed for impact testing is
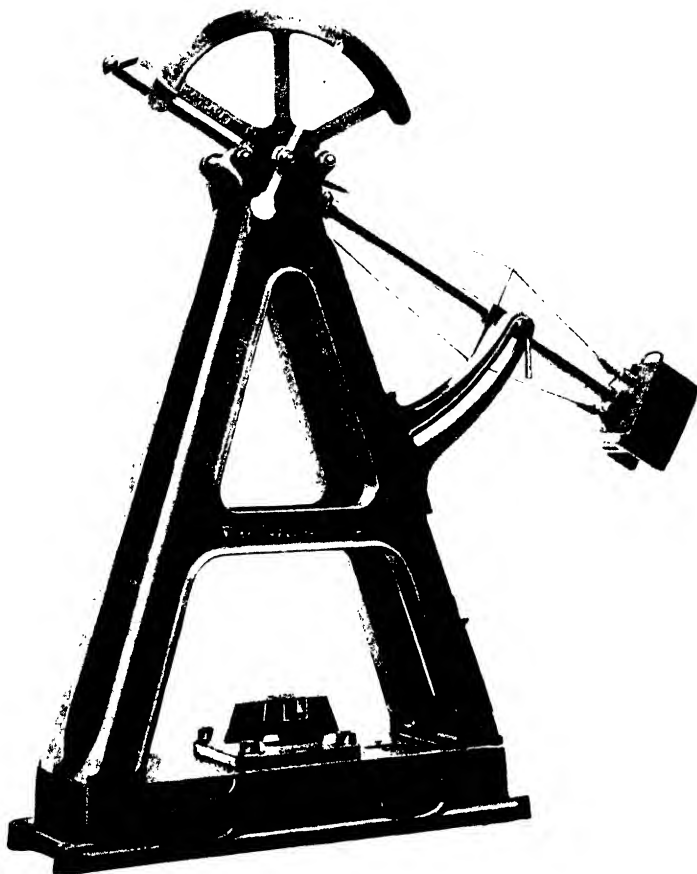
Fig. 29
(By courtesy of W. & T. Avery, Ltd.)

shown in Fig. 29, and the types of test specimens generally adopted are illustrated in Fig. 30. It will be noted that the longer specimens have three notches, so that the average of three tests may be taken, giving results which are more conclusive. The method of carrying out the test is as follows.

The specimen is held in the gripping dies with the notch facing the direction in which the pendulum is to swing when released. The pendulum is then allowed to swing, and at the lowest point in its travel breaks the specimen held in the grips, and proceeds to rise on the other side similarly to a clock pendulum, but to a lesser height than that from which it was

released owing to energy having been absorbed in breaking the specimen. To explain simply—supposing that the vertical height of the pendulum before release is 1 ft. above the striking point on the specimen, and that the weight of the pendulum is 120 lb., assuming the weight to be concentrated at the striking knife edge, and that the vertical height of the pendulum on the other side and at the end of the swing is only 6 in. above the striking point, then

The potential energy of the pendulum
before release . . . . $= A = 120\,\text{lb.} \times 1\,\text{ft.}$
$= 120\,\text{ft.-lb.}$

The potential energy of the pendulum
at the other end of the swing . $= B = 120\,\text{lb.} \times \tfrac{1}{2}\,\text{ft.}$
$= 60\,\text{ft.-lb.}$

Then $A - B = (120 - 60)\,\text{ft.-lb.}$. $= 60\,\text{ft.-lb.}$
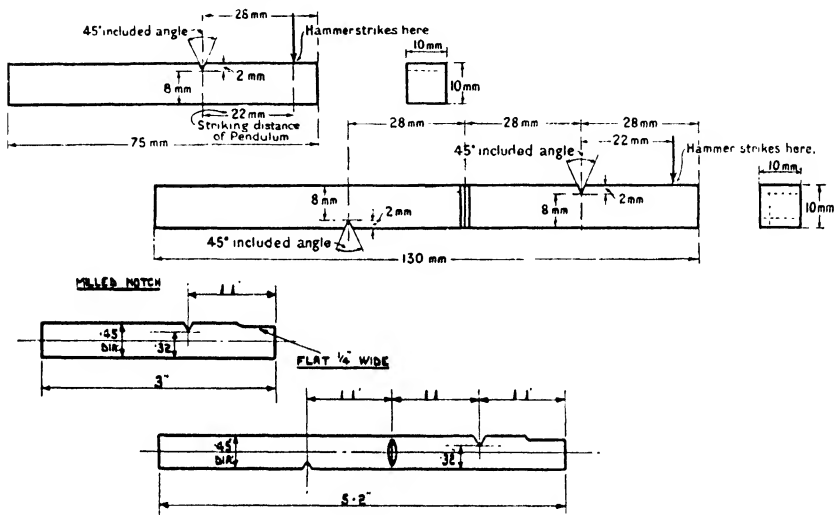
FIG. 30

which is the amount of energy lost by the pendulum in breaking the specimen, and represents the Izod or impact value of the material under test.

To avoid making calculations when testing, the number of foot-pounds representing the impact value of the specimen is registered directly by the pointer which is made to swing over the graduated quadrant, coming to rest at a figure corresponding to the Izod impact value.

Regarding the testing of materials, the candidate would be well advised, whenever possible, to obtain practical experience of testing, coupled with the study of some standard work on material testing.

CHARACTERISTIC DEFECTS OF METALLIC MATERIALS

Under the existing system whereby materials in the majority of cases are fully approved before release from the makers' works, the ground engineer does not generally have to examine such materials for defects until they have been machined or manipulated in the workshop. In any case he should acquaint himself with the nature of the common defects

to which metals are liable in order to ensure that only parts made of sound materials are passed for service on aircraft.

Steel

Steel bars, apart from errors in dimensions and straightness. may be found to contain such defects as *roaks, laps, cracks, seams, draw-marks,*
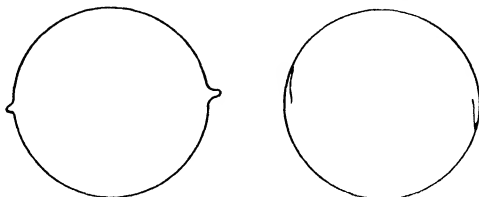
FIG. 31

and *piping.* Roaks may be caused by scale or slag being pressed into the steel and drawn out during rolling. They may be detected by filing or machining the surface of the bar, when they generally appear as dark-
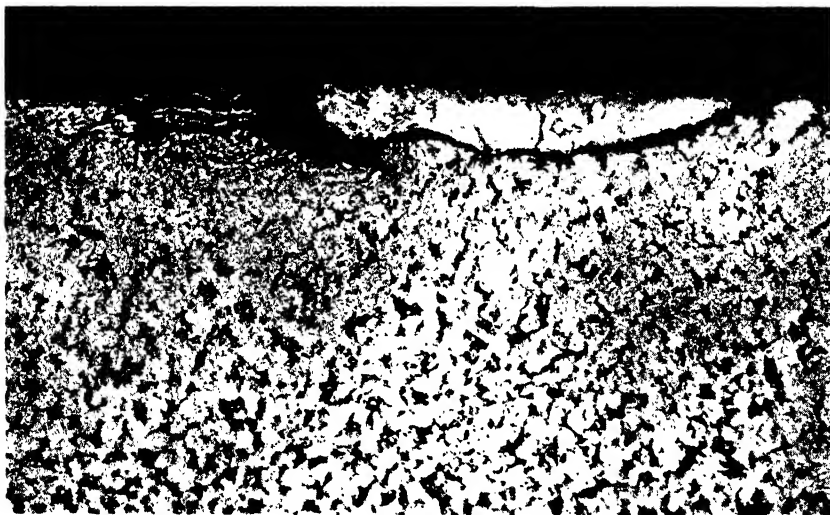
FIG. 32
150 × magnification
(R.A.F. Official. Crown Copyright reserved)

coloured lines. The further defect of cracking may occur in a steel as a development from a roak.

Laps are caused by a *fash* or *fin* (see Fig. 31), which is bent over on to the steel and worked in during subsequent rolling. It is possible for them to extend through the whole length of the bar. If it is possible to remove them completely, or to machine out the part affected, the remaining metal will be useful.

Cracks of various shapes occur in steel bars due to many and various

causes, and if the steel is suspect, and the cracks cannot be readily detected, they may be discovered by the aid of a magnifying glass, or more surely

FIG. 33
100 × magnification
(*R.A.F. Official. Crown Copyright reserved*)

FIG. 34
10 × magnification
(*R.A.F. Official. Crown Copyright reserved*)

shown by soaking the material in paraffin, wiping dry, and then coating the part with french chalk. The presence of paraffin on the chalk would

indicate the possibility of a defect. Steel parts, after hardening and tempering, should be examined for freedom from this defect.

Seams, which may be due to subcutaneous blow-holes or surface cracks in the ingot, run parallel to the length of the bar, and may generally be seen with the naked eye. Should any difficulty arise, however, one of the methods of detection described under "Cracks" should be adopted. Fig. 32 illustrates the transverse section of the edge of a 3.S.1 bar, showing a seam.

Draw Marks, which may be caused by dirt or foreign matter working on to the surface of the dies during the drawing operation, a.e serious if allowed to affect any ultimate work to which the bar is applied. An illustration of an unetched section of the edge of a streamline wire (5.W.3–S.80) shows deep draw-marks partially closed by subsequent rolling (Fig. 33). In this photograph the top part of the photo is solder, which is used for mounting the specimen.

Piping, which may cause defects in the finished bar, is due to axial shrinkage cavities formed in the ingot during solidification.

Defects in steel *Forgings* and *Stampings* may be due to original defects in the steel from which they are made, or which develop in the process of forging or stamping. The possible defects are *roaks*, *laps*, and *cracks*. The forgings or stampings are normally "pickled" to enable these defects to be detected, if they exist. It may be that in the course of machining, certain of the defects will be entirely removed.

CROSS SECTION THROUGH A A SHOWING
V - NOTCHES WHICH MAY CAUSE CRACKS
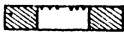
Identification Marking. Although this is not strictly under the heading of steel defects, such stamp impressions as are made for the purpose of identification of the material or of the inspector passing the material, may be a source of trouble unless sufficient care is taken during the stamping operation. In Fig. 34 will be seen a crack which has developed on the surface of a fitting due to stamping a letter too heavily. In this connection, it is recommended that the designer should always indicate on the drawing the position on the fitting or part for identification stamping.

Fig. 35

Occasionally fittings or parts are drilled after identification impressions have been so positioned that the impression of a letter or figure is partly removed by the drilling, as illustrated in Fig. 35. This is bad practice, because it obviously leaves V-notches on the edge of the drilled hole.

Inspection stamps should, wherever possible, have an unbroken circular or oval border. Other markings should be stamped as lightly as possible consistent with legibility.

Steel Sheets or Strips should be examined for all surface defects, including *cracks*, *blisters*, *lamination*, and *buckle*. Lamination may be detected during the operation of a bend test, when the laminated parts will tend to separate. In the case of steel strip, buckle may not at first appear so serious, but if the strip has to be rolled or drawn to a particular section, kinks or even cracks may develop in the finished product due to this defect.

Steel Tubes. Apart from straightness and freedom from kinks, steel tubes should be examined for freedom from such defects as dirt, seaming,

grooving, and lamination. Fig. 36 shows the transverse section of a seam in a T.5 tube.

Aluminium and Aluminium Alloys

Sheet, *Strip*, *Bars*, etc., should be examined for freedom from *dirt specks, blisters, lamination, grooving, spills,* and *buckle.*

A spill, or what is sometimes known as a sliver (illustrated in Fig. 36A) is a surface defect in the nature of a flake of metal adhering to the parent metal, but partially separated from it by a layer of scale, oxide, or other form of non-metallic discontinuity.

Non-metallic inclusion is the original cause of this defect. Some of
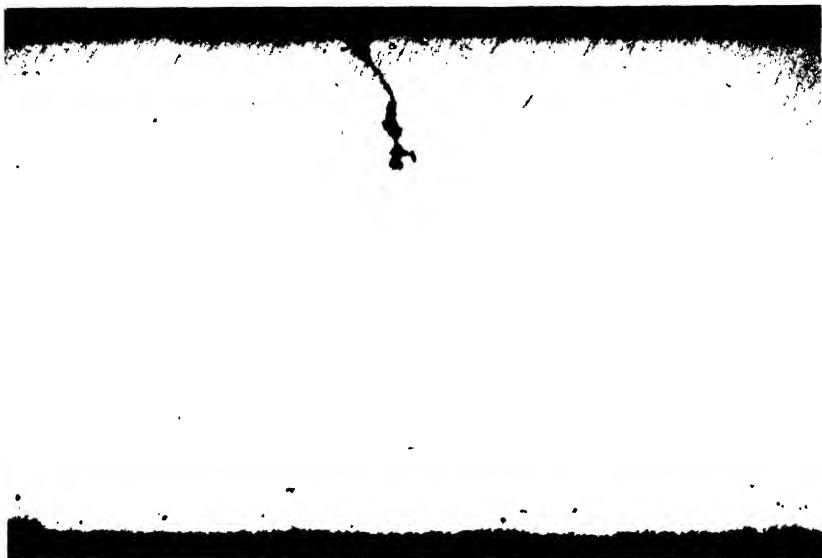
FIG. 36
200 × magnification
(*R.A.F. Official. Crown Copyright reserved*)

these defects may only be revealed after anodizing, which often is the means of showing up surface irregularities which were not detected previously by the naked eye. Small dirt specks are more obvious after anodizing than before, as the anodizing process will not act on such specks, although with careful examination they may be detected before anodizing.

The inspection of wrought duralumin occasionally provides a difficulty due to what appear as local laps or laminations on the surface of a finished part not being pronounced until the part has been anodized. To decide whether these apparent defects are serious or not must be left to the experience of the inspector, because at times they are purely local and may be regarded as insignificant, dependent upon the exact position they will assume in the structural member.

Forgings and *Stampings* should be inspected for such defects as *laps, cracks, offset,* and *insufficient metal.* Laps and cracks often become perfectly obvious after anodizing, a chromic stain appearing in the vicinity

of the defect. Here, again, if the defect is slight, it may possibly machine out, and in any case must be considered on its merits as affecting the strength of the part.

Castings made from any metal are liable to contain *blow-holes*, which are caused by gases being trapped while the metal is solidifying in the mould. Cracks, which may occur due to one of several reasons, are another defect which should be looked for in castings. *Porosity* may be detected by pressure testing in the case of castings on which it is possible to carry out this method of testing. This latter defect and blow-holes, if they cannot be seen from the outside of the casting, can be detected by radiological examination. For castings which are highly stressed, this

FIG. 36A

examination, or, alternatively, the application of a pre-determined proof-load, is imperative to ensure against failure under working conditions.

HEAT TREATMENT OF STEEL

The process of heat treating steel is one of the greatest importance. It must be remembered that aircraft fittings are designed to be as light as possible consistent with strength and resistance to vibration, etc., therefore too much emphasis cannot be placed upon the fact that when a competent authority has laid down a certain heat treatment for a particular grade of steel, the instructions should be rigidly adhered to. For instance, if the temperature range for the hardening of a certain steel lies between 900° and 925° C., if it is only heated to 850° C. it may not be hardened on cooling, and if it is heated to 950° C. some of its useful properties may be ruined.

For the measurement of high temperatures, thermo-couple pyrometers are more widely used than any others, but some accurate means of registering the temperature must always be used. This type of pyrometer consists in principle of two wires of dissimilar metals fused together, and in this form are known as a "couple." If the two metals are respectively connected to a millivoltmeter and then placed in a furnace, on heating an electric current is generated, the electromotive force of which varies with the temperature of the furnace. The couple is enclosed in a tube of silica or similar material, to prevent it being damaged in the furnace.

In order that readings may be taken directly without having to convert, the millivoltmeter is calibrated to read in degrees of temperature.

Pyrometers should be frequently checked against the master pyrometer, and cross-checked at more frequent intervals against each other.

Optical pyrometers, and metallic salts of known melting points are also used for determining furnace temperatures, and are frequently used for checking thermo-couple pyrometers.

Normalizing, a treatment which is used so much in connection with B.S. Specification S.3, for mild steel sheet, means heating the steel to a temperature above its upper critical range, and allowing it to cool freely in air. The steel should be maintained at the required temperature for about 15 min., depending, of course, on the bulk of steel under treatment, and the temperature should not exceed the upper limit of the critical range by more than 50° C. The purpose of normalizing is to remove the internal
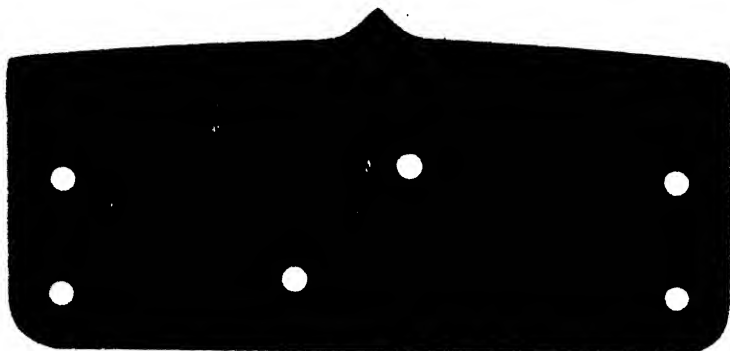
Fig. 36B

stresses set up by welding or bending, and to make the structure of the material uniform throughout.

Annealing consists of heating steel to any predetermined temperature and allowing it to cool slowly.

Hardening consists of heating the steel to a temperature exceeding its upper critical range and cooling it more or less rapidly in water, oil, or air.

Tempering consists of heating the hardened steel to a temperature below the carbon-change point, with the object of reducing the hardness and increasing the toughness.

Case-hardening. The object of case-hardening is to produce parts which have very hard cases with a high carbon content, while the cores, with a low carbon content, remain more or less ductile. The process is carried out by surrounding the parts to be case-hardened with a carburizing material, and heating to a temperature similar to that described for hardening, for about four hours, or such time as will give the required thickness of hard case. At the end of this time, the parts are allowed to cool down slowly in the box in which they were treated.

The parts are then refined by heating to a temperature of between 850° C. and 900° C., at which temperature they are rapidly cooled in water

or oil. The cooling is followed by again heating the parts to a temperature between 750° C. to 800° C. and requenching in order finally to harden the cases.

WELDING OF STEEL PARTS

In addition to the final examination of the welded fittings, it is essential that the processes and materials used in the production of the fittings are satisfactory.

The parts before welding should be clean and free from scale; the welding wire should be of an approved quality, and the gas tested daily by the following method, where gas generators are used.

A piece of white blotting-paper soaked in a 10 per cent solution of silver nitrate should have the gas blown on to it. If, as a result of the blowing, no change in the colour of the blotting-paper is observed, purity of the gas may be assumed. But if the blotting-paper turns brown of any shade, the gas should be changed immediately.

If dissolved acetylene gas is employed, the purity test may take place at longer intervals.

Periodically it is imperative to check, by means of test-pieces, the efficiency of the welder. Dependent upon the class of work being welded, the operator should make the following specimens—

1. Butt welds for tensile and bend tests. The tensile specimen should not break at the weld, while the latter specimen should show no signs of brittleness when bent at the weld.

2. Tube to sheet weld.

3. Tube to tube weld.

(2) and (3) should be sectioned and show a satisfactory depth of weld penetration. For full tests, see Inspection leaflet 39.

In the examination of a welded fitting, it must be visually ensured that a satisfactory joint has been made, and that the material added through the medium of the welding wire is sufficient to form a continuous fillet of regular thickness, and that the bond and penetration are satisfactory.

After welding, the parts should be heat-treated, unless the drawing states otherwise. The heat treatment should be that called up in the relevant specifications for the materials. Special instructions must be sought regarding the question of treatment of a fitting consisting of steels, each requiring a different heat-treatment, as the strength of the one may be impaired by the heat-treatment required by the other.

Subject to drawing requirements, parts made from non-corrodible steels to D.T.D. Specifications Nos. 171, 176 and 207 may be used as welded without subsequent heat-treatment. Non-corrodible steel to D.T.D. Specification No. 166 may be edge and spot welded without subsequent heat-treatment, but the strength of the steel in the vicinity of the weld will be reduced to that of steel to D.T.D. Specification No. 171.

Non-corrodible steels must be welded with rods to D.T.D. Specification No. 61, or with rods of approximately the same composition as the material being welded.

All corrodible steels must be welded with iron or mild steel rods to D.T.D. Specification 82 or with rods of approximately the same composition as the material being welded.

RADIOLOGICAL EXAMINATION
(" X-Ray ")

The extended application of light alloy castings to the stressed parts

of aircraft calls for a more stringent examination of castings than was hitherto the case, and when proof loading is impracticable, "X-ray" examination becomes indispensable,

Fig. 36B illustrates a photograph from a radiological negative of a good casting, and Fig. 36c that of a bad casting, as there is clear evidence of porosity.

The special applications of this examination include castings, forgings, and welded parts in which there is reason to suspect non-metallic inclusions, blowholes, etc.

Certain firms are experienced in this method of examination, and can arrange for certification of parts approved thereby.

Fig. 36c

SOLDERING AND BRAZING

It is very essential that parts involved in soldering and brazing should be thoroughly cleaned by some mechanical means if possible. Where pickling is resorted to, special care should be taken to remove the acid by washing the parts in boiling water, and afterwards heating the parts concerned to a temperature of 150° C. The use of an acetylene flame is definitely forbidden.

The greatest care should be taken to prevent the overheating or burning of the material during the process, that the joint is completely filled with the solder, and that the solder is not run out by overheating. The preferable heating medium is a soft non-luminous gas flame, and in the case of tanks a copper bit must be used.

Soft Soldering

The soldering flux used must be one of an approved brand, and should be tested to ensure that it is free from mineral acid, to avoid the possibility of subsequent corrosion of the material concerned. The flux in use must be issued to the shops daily.

The test on liquid flux is carried out by dipping methyl orange paper into the flux after it has been diluted with an equal volume of water. Should the paper turn pink, mineral acid is indicated, and the flux is unserviceable. Flux in the solid form should be used in accordance with the manufacturers' directions, while fluxes derived from a jelly base must be forwarded for test to an approved laboratory.

Before commencing any soldering operation, it should be ensured that

the solder and the flux are of approved brands, and that the operation is as called for on the drawings.

The soft solder used should be either Grade "A" or Grade "B" of B.S. Specification No. 219/1925. Grade "A" is suitable for sweated joints on steel tubing and similar details. Grade "B" should be used for radiator casings and tanks, and generally for tin and coppersmiths' work.

Cadmium-zinc solder may be used as a substitute for soft solder, in which case suitable fluxes are soldering resin or soldering solution to D.T.D. Specification No. 81. In all cases the parts must be thoroughly washed subsequent to soldering to remove all traces of the flux.

Silver Soldering

This is so-called because the fusible medium consists of an alloy with a high percentage of silver. To form the joint the solder is applied by similar methods to those laid down under "Brazing." Borax is used as a flux, and the solder is most efficiently applied when the flux has been uniformly distributed over the heated surfaces forming the joint.

BRAZING

Whenever possible, a brazing and normalizing bath should be used, so that both operations can be carried out at the same time. The composition of the bath should be copper 55 per cent and zinc 45 per cent. The temperature of the bath should not exceed 900° C.

Sufficient zinc should be added periodically to make up for the loss of this metal by volatilization. A layer of borax and powdered charcoal on the top of the molten metal minimizes the loss of zinc.

Brazing without a bath should be carried out with a brazing metal having a melting point of 900° C., and after the operation is carried out the fittings should be normalized at 850° C. to 870° C. The brazing metal in this case must conform in composition to Grade "A" of B.S. Specification No. 263/1926. In this case a suitable flux is calcined borax.

CORROSION

Consistent with adequate strength, aircraft are designed to be as light as possible. For this and other obvious reasons, it is imperative that all aircraft parts should be protected against the possibility of corrosion.

All metals corrode if exposed to the atmosphere, to a greater or lesser extent, but aluminium alloys and steel suffer to a dangerous extent in this respect unless protected by an approved method. In the main, only the surfaces of the metals are attacked, but duralumin, for instance, is liable in addition to intercrystalline corrosion, which is much more deleterious than surface corrosion. Intercrystalline corrosion attacks the crystal boundaries, and its presence can only be discovered by microscopic examination, or bending the suspected part, the former method generally being impracticable, and the latter may so deform the part as to render it useless. The various methods of protecting metals are described in the following pages, a study of which is essential to the Ground Engineer.

The following general facts regarding corrosion should be noted by those associated with Design and Inspection—

1. Annealed duralumin, when in contact with normalized duralumin, will corrode rapidly.

2. The contact of dissimilar metals facilitates corrosion; instances of this are brass screws in duralumin, or duralumin riveted to steel. This is due to galvanic action.

3. Leather, when wrapped round unprotected metal parts, causes rapid corrosion.

4. Moisture or air that is at all humid aids corrosion. For this reason it is very essential that parts to be coated with paints or enamels shall be as dry as possible before coating. Cases are on record where painted metal faces have become rusty under the paint in consequence of the coating having been applied while the surface of the metal was wet when painted.

5. Dirt and foreign matter in any shape or form facilitates corrosion. As pointed out elsewhere in this book, cleanliness minimizes any prolonged action of corrosive deposits.

PROTECTIVE PROCESSES
Anodic Oxidation

This process is carried out to protect aluminium and aluminium alloys, including duralumin, against corrosion, and consists of forming an oxide on the surface of the parts so treated.

Briefly, the process is that of suspending the parts to be treated as anodes in an electrolyte, which consists of a 3 per cent solution of chromic acid in distilled water, or water which has been approved for the purpose. The chloride content must not exceed the equivalent of 0·20 grm. sodium chloride per litre. The cathodes are generally formed of graphite plates.

The solution will function satisfactorily with a strength of $2\frac{1}{2}$ per cent of chromic acid, and it is essential that the solution be checked from time to time to determine that the acid does not fall below this percentage. The temperature of the bath should be maintained at $40°$ C. $\pm$ $4°$ C. The bath should also be provided with some sort of mechanical stirrer in order to keep the solution circulating. Three to four amperes per square foot of treated surface is the current density generally employed.

The voltage across the bath is steadily increased from 0 to 40 volts during the first 15 min.; it is then maintained steadily at 40 volts for the next 35 min.; 40–50 volts for the following 5 min.; and is finally maintained at 50 volts for the last 5 min., the entire process lasting one hour.

The question of cleanliness is of extreme importance in this process, and the parts must be washed in petrol, benzol, or solvent naphtha, with a final washing in hot water and drying immediately prior to being treated in the bath.

After treating, the articles must be thoroughly washed in hot water and dried.

In the case of built-up parts, which are very liable to "pit," test samples must be treated with the parts and afterwards disintegrated to ensure absence of this defect.

"Pits" are formed as the result of air bubbles remaining between two adjacent surfaces of a built-up part, and where these bubbles exist, the current "arcs" across, and at the point of arcing, the metal is burned.

The test on the coating is usually that of visual examination, but a check test may be made by marking the parts with an indelible pencil or by the application of any cheap dye, which will not remove with a damp cloth if the coating is satisfactory.

Electro-deposited Zinc and Cadmium Coatings for the Protection of Steel Parts

The first step in ensuring that parts are efficiently coated by either of these processes is to examine the plating bath and its contents. The composition of the bath and its control should be such as to produce a satisfactory job.

Among the methods adopted for preparing the details for treatment are washing in a hot caustic bath, sand-blasting with fine sand, or polishing with emery. Cleaning by acid pickling should be avoided.

The electro-deposit process should not be applied to built-up strip and sheet steel parts, welded tubular components, and welded hollow components generally, from which it would be difficult to remove the last traces of the plating solution. These parts should be protected both externally and internally (unless the tubular members are closed at both ends) by means of stoving enamel, cellulose enamel, or pigmented oil varnish.

The thickness of the coating, which should not be less than ·0003 in., can be determined either by weighing the article before and after coating, or by definite measurement.

In order to remove any brittleness as the result of this process, the parts treated should be washed in cold water and heated for not less than 30 min. at a temperature between 100° C. and 200° C.

Check bend tests should be carried out on selected treated parts, and in the case of large parts a test piece of similar material should be plated simultaneously for the subsequent testing.

A check is also essential to see that the necessary limits controlling the fitment of the plated parts have not been exceeded due to the thickness of plating.

Stove Enamelling

This process consists of applying an approved enamel by dipping, spraying, or brushing, and afterwards heating the coated part in a special stove at a temperature not exceeding 170° C. for approximately $2\frac{1}{2}$ hours. This temperature limit is important, because of the soft solder on soldered parts melting at approximately 180° C., and in consequence of this the temperature should be very carefully controlled. Two thermometers should be in constant use, one near the lower portion of the stove, and the other in the region of the enamelled parts. The parts to be coated should be cleaned with methylated spirit or other approved cleansing medium.

The enamel should be frequently checked for consistency and viscosity by means of a hydrometer, because the consistency of the enamel will vary in accordance with the evaporation of the volatile solvent. Approved thinners should be added when necessary.

It is particularly important to note that the parts being treated contain no trapped spaces, and for this reason there should be an exit through which the enamel may drain in cases of boxed-up or tubular structures.

It has been found that stove enamelling finally heat-treated duralumin decreases the ·1 per cent proof stress and ultimate tensile stress figures. In consequence of this a representative test specimen should be heat-treated and stoved with each batch of duralumin parts to ensure that the test figures do not fall below those required by the specification for the material.

ALUMINIUM AND OTHER LIGHT ALLOYS

Aluminium in the form of sheets is now extensively employed on aircraft for such substructures as fairings, cowlings, and brackets. It is also used in the form of tubes in places where stress is not of importance. It has a specific gravity of 2·6, which, for equal volumes, is one-third of the weight of steel. The sheets, which consist of not less than 98 per cent

pure aluminium, are used in the hard, half-hard, and softened conditions, which have the following tensile strengths—

> Hard,   not less than 9 tons per sq. in.
> Half-hard, not less than 7 tons per sq. in.
> Softened, not less than 5 tons per sq. in.

The softened sheets are very adaptable for spinning, and in the hard condition are largely used for the shells of petrol and oil tanks.   The only tests called for in the relevant specifications are those of tension and bending, although all of the sheets are examined for freedom from surface defects and buckle, also that they are bright, clean, smooth, and free from discoloration, blisters, and lamination.   The limits of thickness laid down vary from $\pm$ ·001 in. for a thickness of ·012 in., to $\pm$ ·018 in. for a thickness of ·3 in.

The use of pure aluminium, however, is limited, owing to its low tensile strength.   Light aluminium alloys are, however, used in the form of bar, sheet, strip, tube, forgings, and castings.   In the wrought condition, the light aluminium alloy known as duralumin has a chemical composition of—

> Copper,   between 3·5 and 4·5 per cent.
> Manganese, between ·4 and ·7 per cent.
> Magnesium, between ·4 and ·7 per cent.
> Silicon,   not more than   ·7 per cent.
> Iron,   not more than   ·7 per cent.
> Titanium,   not more than   ·3 per cent.
> Aluminium, the remainder.

Although the specific gravity of duralumin is only 2·85, yet it has the following mechanical properties—

> ·1 per cent Proof Stress, not less than 15 tons per sq. in.
> Ultimate Tensile Stress, not less than 25 tons per sq. in.
> Elongation,   not less than 15 per cent.

when the material is in the normalized condition.

In a similarly heat-treated condition, the ultimate tensile strength of sheet and strip in this alloy is not less than 25 tons per square inch, and a proof stress of not less than 15 tons per square inch.

The method of determining the proof stress of duralumin is similar to that laid down for high tensile steel, as may be gathered by comparing the curve in Fig. 36D with that in Fig. 38.   When testing duralumin, the testing machine employed should possess an accuracy and sensitivity preferably within 5 per cent of the maximum load applied to the test piece.

The annealing and normalizing processes are dealt with under the section on "Heat-treatment of Duralumin."

Among the various aluminium alloy castings is that known as the "Y" alloy, which has a composition of—

> Copper,   between 3·5 and 4·5 per cent.
> Nickel,   between 1·8 and 2·3 per cent.
> Magnesium, between 1·2 and 1·7 per cent.
> With certain small percentages of impurities, and
> Aluminium the remainder.

This alloy casting has a tensile strength of not less than 10 tons per square inch in the "as cast" condition, and 14 tons per square inch in the heat-treated condition.

STRAIGHT LINE OF PROPORTIONALITY

·1% OF GAUGE LENGTH

MAX. STRESS 26·5 TONS PER SQ. IN.

·1% PROOF STRESS

STRESS IN TONS PER SQ. IN.

TYPICAL STRESS STRAIN DIAGRAM FOR DURALUMIN SHEET IN THE NORMALISED CONDITION "AGED" FOR 5 DAYS

·002"   ·004"   ·006"   ·008"   ·01"   ·012"

STRAIN — EXTENSION IN INCHES
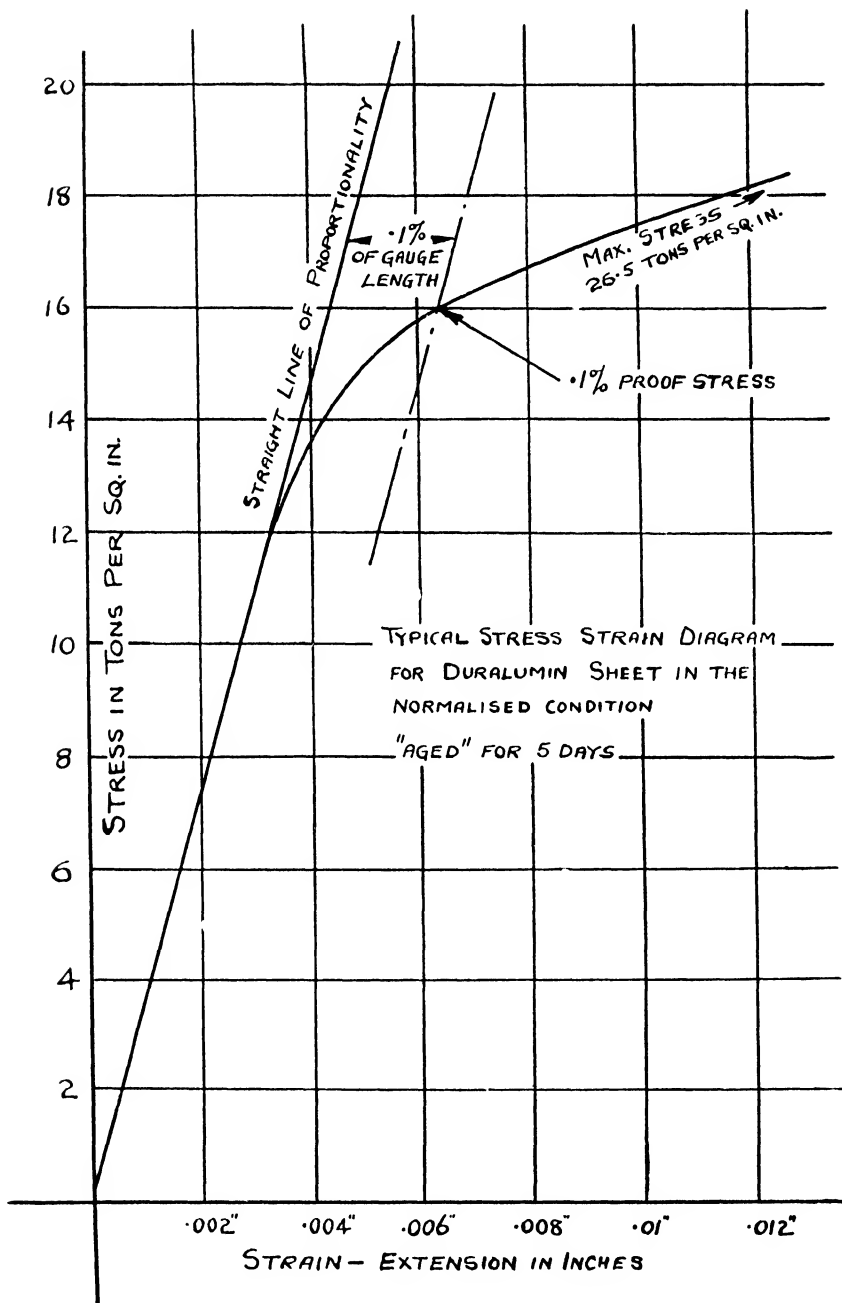
FIG. 36D

The heat-treatment consists of heating the castings to a temperature of 500° C. to 520° C. for not less than six hours, and quenching in boiling water. The other varieties of this alloy contain varying amounts of copper and zinc, according to the particular specification, while an outstanding aluminium alloy casting has a silicon content of 10 to 13·5 per cent, the special feature of which is its resistance to corrosion.

The application of aluminium alloy castings to aircraft is dependent upon design, but should they be employed in any position where strength
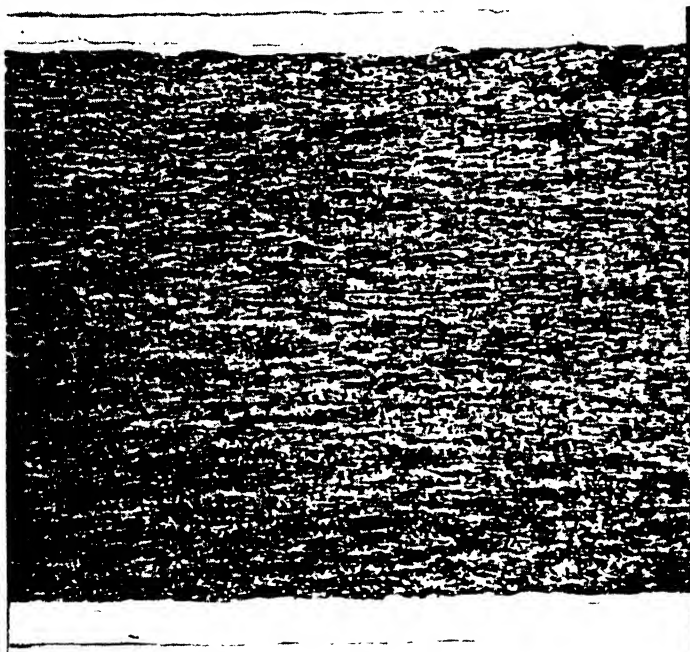
FIG. 36E
Full cross-section of 14 gauge " Alclad" sheet. Mag. 50X,
Etched 1% HF.

is of importance; they should be radiologically examined for porosity and blow-holes, or, alternatively, subjected to a predetermined proof-loading.

ALCLAD

This product has been specially designed for use in aircraft, where a material combining light weight and high strength with exceptional corrosion resistance is of special importance. The sheet consists of a core of strong alloy, with a coating of high purity aluminium on each surface, which in addition to protecting the alloy where the covering is complete, also electrolytically protects the base metal when exposed at sheared edges or by deep scratches or abrasions. It also affords substantial electrolytic protection to rivets of the base metal.

It combines the properties of the strength of duralumin and/or super duralumin with the resistance to corrosion of aluminium. In the pure state aluminium offers a marked resistance to corrosion. Fig. 36E shows

a full cross-section of alclad. There is an intermediate diffusion zone between the strong alloy and aluminium which is due to the diffusion of copper and probably the magnesium-silicon constituent of the strong alloy into the pure aluminium during the manufacture and heat-treatment of the alclad. This diffusion takes place only at high temperatures.

Alclad is now used extensively for structural work in aircraft and for such parts as stringers and shell plating of hulls and floats in seaplanes.

Its specific gravity is not greater than 2·85.

The specifications covering Alclad are B.S.S. L.38 and D.T.D. 275.

The material to L38 should give the following test results—

Tensile Test

0·1 per cent proof stress (for sheets and strips thicker than 25 S.W.G. only)	not less than 13·5 tons per sq. in.
Ultimate Tensile Stress (all thicknesses)	not less than 24 tons per sq. in.
Elongation (on 2 in.) (for sheets and strips thicker than 12 S.W.G.).	not less than 15 per cent.

While the following figures are demanded for material to the D.T.D. Specification 275—

Tensile Test

0·1 per cent proof stress . .	not less than 16 tons per sq. in.
Ultimate tensile stress . .	not less than 26 tons per sq. in.
Elongation (for sheets and strips thicker than 12 S.W.G.) . .	not less than 15 per cent.

The following bend tests are applicable to both specifications—

Single Bend Test.

Applicable only to sheets and strips 12 S.W.G. (0·104 in.) and thinner.

Each test piece must withstand, without cracking, being bent through 180° round a radius of equal to three times the nominal thickness of the sheet or strip.

Ninety degrees Reverse bend Test.

Applicable only to sheets and strips 12 S.W.G. and thinner.

Each test piece is bent round a specified radius, dependent on the thickness of the specimen, at right angles to one end which is fixed in a vice. It is then bent back to the original position. This operation is repeated, and the specimen must withstand, without cracking, reversals ranging from one to nine, according to the thickness of the material.

The material is softened by heating to a temperature between 360° and 400° C., and cooling in air or water. All softened material must be finally heat-treated at 490° C. plus or minus 10° C. and quenched in water or oil.

ALPAX

This is a silicon aluminium alloy casting conforming to B.S. Specification L.33, with a specific gravity not greater than 2·7. This material is particularly useful when forming intricate castings, as the high percentage of silicon facilitates the flow of the molten metal. It has the following analysis—

Silicon between	10 and 13 per cent
Iron not more than . .	0·60 per cent
Manganese not more than . .	0·50 per cent
Zinc not more than . .	0·10 per cent
Titanium not more than . .	0·20 per cent

Total other metallic constituents (excluding those used as modifying agents)

Not more than . . . . 0·10 per cent

Total modifying agents (namely, sodium, tungsten, chromium, cobalt, boron and calcium)

Not more than . . . . 0·3 per cent
Aluminium . . . . . the remainder

The mechanical properties, if the alloy is sand cast, are as follows—

0·1 per cent proof stress not less than . 3·5 tons/sq. in.
Maximum stress not less than . . 10·5 tons/sq. in.
Elongation not less than . . . 5 per cent

whereas if cast in a chill mould, the following results may be expected—

0·1 per cent proof stress not less than . 4·5 tons/sq. in.
Maximum stress not less than . . 13·0 tons/sq. in.
Elongation not less than . . . 8 per cent

ELECTRON

This is a magnesium alloy which is now being extensively employed on aircraft for such parts as control wheels, axle blocks and chain guards. It has a specific gravity not greater than 1·83.

There are Specifications covering this class of material in the form of castings, sheets, bars and forgings.

D.T.D. Specification No. 59.A for castings requires a chemical composition of—

Aluminium not more than . . . . 8·5 per cent
Zinc not more than . . . . . 3·5 per cent
Manganese not more than . . . . 0·5 per cent
Impurities not more than . . . . 1·7 per cent
Magnesium . . . . . . the remainder

With a maximum stress of not less than 9 tons per square inch, and an elongation of not less than 2 per cent.

Magnesium alloy bars to D.T.D. Specification 259 have a chemical composition of—

Aluminium not more than . . . . 11·0 per cent
Manganese not more than . . . . 1·0 per cent
Zinc not more than . . . . . 1·5 per cent
Impurities not more than . . . . 1·5 per cent
Magnesium . . . . . . the remainder

and the mechanical properties are—

Up to 2 inches diameter:

Maximum stress not less than . . . 17 tons/sq. in.
0·1 per cent proof stress . . . . 10 tons/sq. in.
Elongation not less than . . . . 10 per cent

Over 2 inches diameter:

Maximum stress not less than . . . 14 tons/sq. in.
0·1 per cent proof stress . . . . 9 tons/sq. in.
Elongation not less than . . . . 5 per cent

HIDUMINIUM

This aluminium alloy to B.S.S. Specification L.40 is supplied in the form of bars, extruded sections, and forgings.

It is commonly known as "Hiduminium RR 56." The specific gravity is not greater than 2·8. It has a chemical composition of—

Copper,	between 1·5 and 2·5 per cent.
Nickel,	between 0·5 and 1·5 per cent.
Magnesium,	between 0·6 and 1·2 per cent.
Iron,	between 0·8 and·1·5 per cent.
Titanium,	not more than 0·2 per cent.
Silicon,	not more than 1·0 per cent.
Aluminium,	the remainder.

When intended for aeronautical purposes, it is subjected to the following heat-treatment—

It is heated uniformly to a temperature between 510° and 535° C. and quenched in water, and afterwards aged by heating between 155° and 175° C. for 10 to 20 hours. This ageing may be accelerated by heating at a temperature between 195° and 205° C. for a period not exceeding 2 hours.

After this treatment and ageing, it must conform to the following mechanical tests—

0·1 per cent proof stress	.	not less than 21 tons per sq. in.
Ultimate tensile stress	.	not less than 27 tons per sq. in.
Elongation . .	.	not less than 10 per cent.

Hardness tests are carried out on the representative test pieces, and the hardness of the bars, forgings, or extruded sections shall not be more than 10 per cent less than that of the test piece.

Other specifications provide for this class of material in the form of castings.

HEAT TREATMENT OF DURALUMIN

For the purpose of working, bending, and workshop manipulation, the duralumin should be annealed, which consists of heating the material in a salt bath to a temperature of 380° C. ± 10°, and cooling in air, and after working, normalizing at a temperature of 490° C. ± 10° C., after which it should be cooled off in water. The normalizing temperature should never exceed 500° C., as there is a danger of embrittling the material. This latter precaution is equally applicable to Alclad.

For simple bends or slight working, the material may be in the normalized condition, but the cold working must be completed within two hours of quenching. For more drastic working duralumin should always be annealed.

Rivets are used only in the normalized, or finally heat-treated, condition. Immediately before use they should be soaked at the normalizing temperature for a period of 15 to 30 min., and the riveting completed within 1 hr. after treatment.

Duralumin should never be left in the annealed condition for service on aircraft; it is much weaker than in the normalized condition, and further. is much more liable to corrode.

The reason for the time limit stipulations regarding the working of duralumin is that after normalizing the material "ages" or hardens; at first fairly rapidly, and then slowly. If drastically worked after age-hardening, cracks may develop.

The temperature for forging or stamping duralumin should be between 400° C. and 450° C., but never below 400° C., or cracking generally occurs.

HIGH TENSILE STEELS

Concurrent with the development of "all-metal" aircraft, came the extended application of high tensile steels to their construction. From the weight standpoint, low or medium carbon steels of a comparatively low tensile strength were ruled out of the question. Plain high carbon steels could be hardened and tempered to a degree which would give them sufficient strength, but they would not be sufficiently ductile for the required degree of manipulation, or for the work to which they would be applied.

The employment of steels which rely for their improved mechanical properties on the addition of comparatively small amounts of such elements as nickel, chromium, manganese, tungsten, molybdenum, and vanadium, became very popular, and that popularity has been maintained.

The addition of nickel, besides generally improving the qualities of the steel, definitely increases the toughness, and raises the elastic limit. Case-hardening steels, which are mainly used for engine parts, contain from 3 per cent to 5 per cent of nickel. Chromium increases the hardness of steel, and gives to it that quality known as "air hardening." Stainless steels contain not less than 12 per cent of chromium. Tungsten imparts air-hardening qualities and increases the ability of the steel to retain its hardness and strength at comparatively high temperatures. Other elements are added in varying amounts, to obtain improved results and special characteristics, for instance—

> ·25 per cent Vanadium
> ·65 per cent Molybdenum
> 1·0   per cent Tungsten

when added to steel avoids what is known as "temper brittleness," molybdenum being the most effective element in this respect. Sulphur and phosphorus are impurities in steel, and an excess of either, or both, causes the steel to be very brittle.

These steels, which are generally known as alloy steels, are now used extensively in the manufacture of spars, longerons, struts, and wing ribs of different sections, dependent upon the various designs.

In aircraft works, the steels for making the above parts are mostly worked in the form of strip as supplied by the steel maker. Dependent upon the specification, the strip may be supplied either in a fully heat-treated condition for forming or manipulating to the required section without further heat treatment, or in an annealed condition to be rolled or drawn to section and subsequently hardened and tempered. Using the former of these two alternatives, the aircraft manufacturer has no problem of heat treatment to settle, but with the latter, special methods of heat-treatment have had to be devised for dealing with the long lengths of the sections in question.

Small items made from steel in this form may be hardened and tempered in the normal manner, but with such sections as are used for spars, longerons, etc., even if furnaces of sufficient length were installed to cope with such parts, the difficulties of twisting or warping and of uniform cooling would be practically insurmountable if dealt with by the ordinary methods.

A brief description of the special methods of heat-treating such parts employed by Sir W. G. Armstrong-Whitworth Aircraft, Ltd., Coventry, and Messrs. Boulton & Paul, Ltd., Norwich, follows.

The Armstrong-Whitworth method of heat-treating steel strip and

sections formed therefrom is known as the "Tension Electric" treatment. It consists of heating the steel to the required temperature by placing the part to be treated in an electric circuit while the part is held in tension by special clamping dies secured at the ends of the part.

The resistance of the steel to the current causes the temperature to
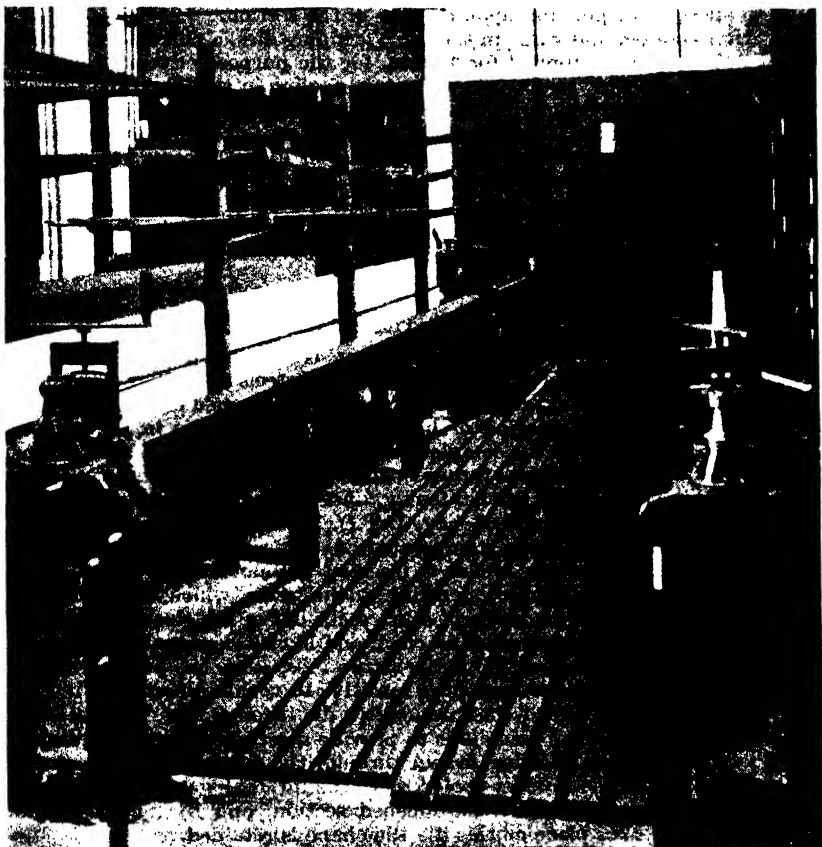
rise quickly, and the complete heating operation for either hardening or tempering lasts only from one to three minutes, dependent upon the section under treatment.

The object of keeping the steel under tension is to prevent it from warping and twisting, and to counteract sag due to the weight of the section, which would naturally take place while the material was being subjected to the high temperature of hardening or tempering.

It is necessary to vary the voltage in accordance with the length of the part, and the amperage with the different cross-sections. Scale is only formed during the hardening process, but this becomes disintegrated during cooling. The reduction in thickness caused by the scaling is negligible.

Considering a 12 ft. length of 20 S.W.G. strip of typical air-hardening steel shaped in a manner suitable for a spar web about 2 in. overall width: it is hardened by heating to 880° to 890° C. by a current of 70 volts and 1,100 amperes, while under the tension of 1 ton per square inch. The current is only maintained for 1 min., and when cut off the part cools in the still air of the hardening shop while still under tension, or is subjected to an air blast, depending upon the size of the section.

After cooling, and while in the same gripping dies, a current of 31 volts and 240 amperes is applied for 1½ min. for the purpose of tempering at a temperature of 410° to 430° C., and again cooling in still air. The tension maintained during tempering and cooling is 8 tons per square inch.

The temperatures are checked by means of an optical pyrometer, salts, or standard thermocouple. The illustration in Fig. 37 shows two lengths of steel undergoing heat treatment.

Before the heat-treated part is passed for shop manipulation, it is tested on a diamond hardness-testing machine. Apparatus is also in existence for hardening and tempering by the above method, but including water or oil cooling.

CONTINUOUS HEAT TREATMENT PROCESS

The Boulton & Paul continuous heat treatment process has been developed to provide for the heat treatment of steels after they have been formed into the desired section. The sections are formed either by rolling or drawing or a combination of both, whilst the strip is in the soft or annealed condition. On the completion of this forming process, the sections are passed through electrical furnaces, there being at the present time two distinct operations—pass for hardening, and one for the tempering.

For the heat treatment of, say, D.T.D. 54, the hardening furnace is set at about 860° C., which temperature is controlled automatically by means of a thermocouple, which is inserted permanently in the furnace chamber, this thermocouple operating an indicator which by being set at any predetermined reading will cause a cut-out of the electrical current when the desired temperature is reached, and likewise cause the current to be switched on again when the temperature falls below the predetermined value. In practice the instrument is sensitive to within about ± 3°.

At the entrance end of the furnace is a die through which the section is passed. The object of this die is to provide a certain amount of tension to the strip when it is being drawn through the furnace. At the outlet side of the furnace is a water-cooled die. The internal shape of this die is the exact shape required of the finished section, and by means of the cooling which takes place at this die the shape is retained.

The furnace and dies are mounted on the ordinary strip-forming draw-benches, and the passage of the strip through the dies and furnace is controlled in exactly the same manner as is the strip when being cold worked.

The operation of tempering is carried out in exactly similar manner, except that in this case the furnace is about twice the length of the hardening furnace, to ensure a satisfactory soaking operation.

TESTING HIGH TENSILE STEELS

The methods employed in testing high tensile steels closely follow those already described for mild steel, with the one important exception that a minimum proof-stress is called for in a number of the specifications of this class of material.

The proof stress is defined as the stress at which the stress-strain curve

departs by ·1 per cent of the gauge length from the straight line of proportionality. Other percentages of the gauge length are occasionally stipulated, but the principle of obtaining the proof stress is the same.

Comparing the stress-strain diagram shown in Fig. 28 with that shown
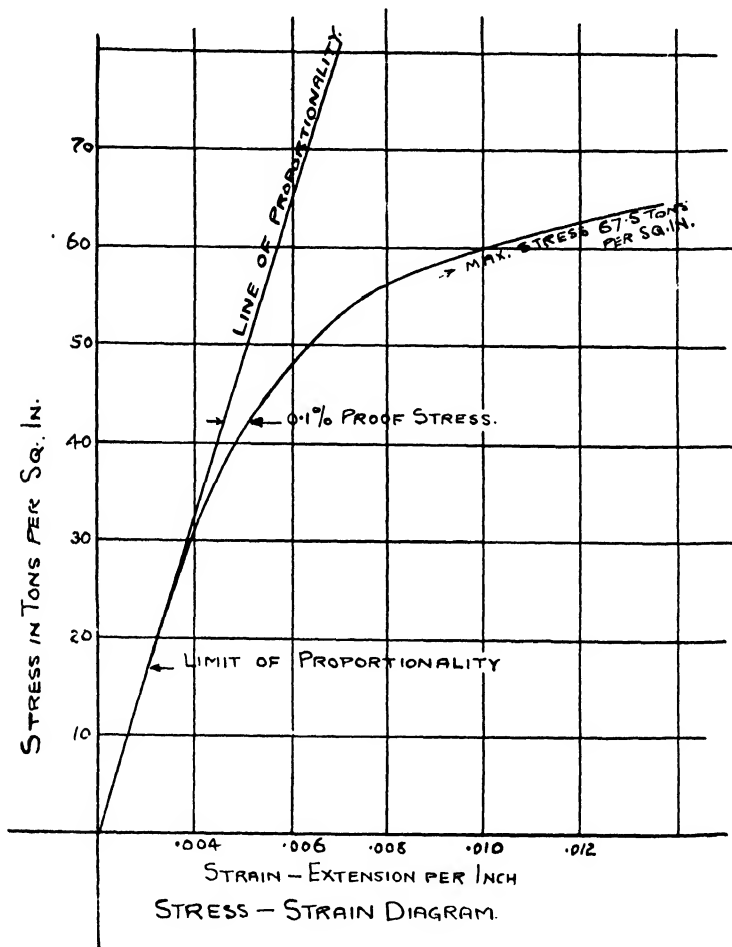
FIG. 38

in Fig. 38, it will be seen that the curve for high tensile steel in this instance is regular, and there are no points indicating elastic limit, or yield point, and it further illustrates the necessity for determining the proof stress as a means of demonstrating the elastic property of the steel.

The straight line of proportionality is drawn as nearly as possible through the portion of the stress-strain curve, which indicates the amount of extension of the specimen as proportional to the stress.

INSPECTION OF AIRCRAFT COMPONENTS BEFORE COVERING

THERE are special points which apply to the construction of each particular component, but the following notes will be of use on all components during the construction and inspection.

All struts should be straight within the limit of 1 in 600 for bow. Although this bow is allowable, it is preferable that the advantage of the limit is avoided. The cause of bowing is generally attributable to either uneven bedding at the ends of a strut, or the overtightening of the bracing wires, that is assuming, of course, that the strut was perfectly straight before insertion.

During construction any parts which will ultimately be hidden when the component is finally examined should be inspected at the time of fitment. If parts are drilled in position, before they are finally assembled, they should be removed for examination, or alternatively, a special inspection should be carried out before the bolts, rivets, or taper pins are finally inserted.

FIG. 39

Turnbuckles should have the threads completely engaged in the barrel, with room left for further adjustment, or, if of the fork-end type, the thread should be engaged beyond the inspection hole, and not so far as to foul the end fitting, and when finally adjusted, the turnbuckle should be locked in an approved manner with the locking wire.

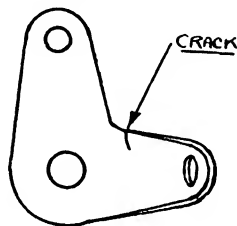The careful examination of fork-ends and bracing wires when in position is of greatest importance. The fork-ends should be in line with the wiring lugs, to which they are connected, or the connecting pins will not be bedding throughout their length. The split pin securing the connecting pin should be in position and properly opened. The thread of the bracing wire should be engaged just beyond the inspection hole in the fork-end, and not so much beyond as will cause fouling on the fitting. When a bracing wire is finally adjusted the locknuts should be tightened at each end of the wire.

Tie-rods and streamline wires should always be checked in respect of the identification and inspection stamps. All nuts should be locked by riveting or other approved method.

All metal fittings should have been inspected to the drawing requirements for correctness of material, accuracy of dimensions, angles, pitch of holes, that the correct heat treatments have been carried out, and that there is no evidence of cracks. Too much stress cannot be laid upon the importance of the removal of sharp or raw edges, as many failures have occurred in consequence of cracks developing from the rough edges left on fittings. A typical illustration is shown in Fig. 39.

Bolt heads and nuts should be properly bedded down. High tensile bolts and nuts are now distinguishable by a groove cut around the hexagon, which facilitates inspection of these details in this respect after assembly.

The use of a scriber for marking lines on wood or metal parts should be avoided, as such marking may cause the commencement of a failure.

Whenever a tube or similar structural member is fitted into a socket, that it is properly fitted, pinned, and bedded at the end of the tube must

form a definite inspectional operation. In like manner, liners and similar fitments which are inserted in tubes, spars, or any other hollow structural parts, must be inspected for position.

In conjunction with this inspectional operation, every case of such a fitment must have an individual stamp applied in a manner that it will not be easily defaced. To facilitate this and subsequent inspections, a "sight," or inspection hole or holes, must be provided, as indicated in Fig. 40.

Particular attention should be paid that all fittings are in their correct position, especially fittings which at first sight appear identical with those in other and similar positions, and yet closer examination reveals that there is some slight difference, perhaps only in one dimension.

A component which is built in a jig, as is often the case, should always be checked for alignment after removal from the jig, because after removal it may spring or twist due to the stresses set up during riveting, bolting, or fixing of the details. An aileron, for instance, may be assumed to be satisfactory

FIG. 40

when in the jig, yet on removal the spar may bow and throw the hinge fittings out of alignment, due to the pull of the ribs, etc., which have been put on and fixed to the spar while in the jig.
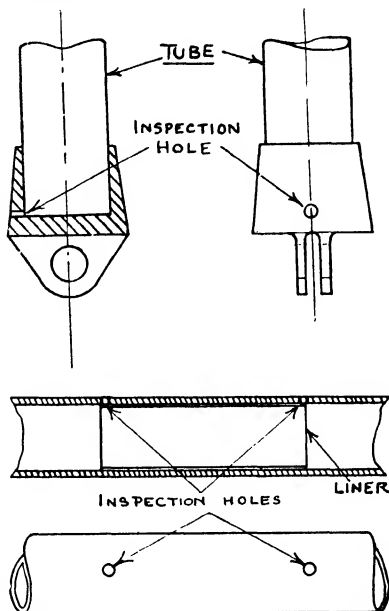
TRAMMELS

This measuring tool, which is similar in application to a pair of draughtsman's dividers, with the exception that the "points" are adjustably

FIG. 41

mounted on a beam of wood or metal, is so frequently used in checking components for squareness, etc., that a special description of its use is deemed advisable.
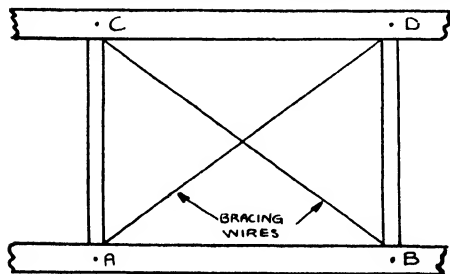
Consider the frame shown in Fig. 41, in which, for illustration purposes, AB and CD are portions of the front and rear spars of a mainplane, while AC and BD are compression struts of equal length at right angles to the parallel spars, and connected by pins at their ends to eye-bolts attached to the spars.

First tighten the bracing wires until the strain is lightly taken. By

using the trammels, the points A and C are marked off in the centre of the spars and at equal distances from the ends of the respective spars, and approximately on the centre line of the strut AC.

If the plane is so designed that the inner end rib is not square with the spars, that is so far as squareness is concerned, one spar end projects beyond the other, due allowance should be made for this when marking the points A and C.

Point B is marked off on the centre of the spar and approximately on the centre line of the strut BD. Point D should be marked at the intersection of the arcs struck from C with a radius equal to AB and from B with a radius equal to AC. Incidentally, these centre points should be impressed on clip plates attached to the top of the spars, and not on the spars, in order to avoid the possibility of damaging the spar flanges.

The bracing wires should now be adjusted and equally tensioned until the distance AD exactly equals CB, when measured by the trammels. A watch should be kept during any adjustment of the wires that the spars are out of winding. The amount of tension taken by the bracing wires is a matter which is settled by the experience of the operator, but it is needless to say that they should not be over-tensioned, and if under-tensioned, their function will not be fulfilled.

SPLICING OF CABLES

In Fig. 42 is an illustration of an approved type of splice as adopted for control cables.

The use of a thimble inside the cable loop is to prevent the wear of the cable wires, and to avoid the loop becoming deformed when under stress or working conditions.
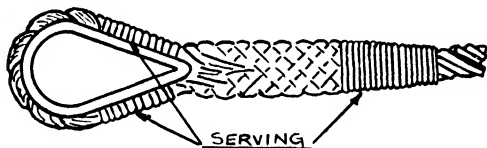
SERVING

FIG. 42. CABLE SPLICE

The waxed serving on the wire on each side of the thimble is to prevent the cable from unwinding during the splicing operation. The completed splice consists of four and a half tucks. The first three tucks are to be left free of serving, and the waxed thread applied sufficiently to cover the bare end of the wires only.

After splicing and before use, each cable should be proof-loaded to the extent of half the specified minimum breaking load for the size of cable involved.

All completed cables should have an identification tab carrying the part number of the cable, together with the inspector's stamp number.

In order to test the efficiency of the splicer, test specimens should be made spliced at both ends and tested in accordance with the specification requirements.

RIVETING

This process, which is very extensively employed in all parts of aircraft construction, requires the greatest care and attention both during the preparation of the parts for riveting and during the actual riveting operation.

Inspection is facilitated by producing specimen joints representative of the work under inspection, and having these joints sectioned and examined, as the external appearance will not always reveal defective riveting.

Among the essential points to be watched in the riveting process are the following—

1. That the drilling or punching (if authorized) has been satisfactorily carried out, and that the holes are clean and of correct size and pitch.

2. That all burrs are removed from each hole, and all swarf from between the surfaces to be joined.

3. That all rivets are correct to drawing requirements and specifications.

4. That all heads formed in the riveting process are free from cracks and are of the correct shape, definitely securing the work without distortion or damage to the rivets or to the riveted parts. Fig. 43 illustrates a few of the typical defects in riveting.
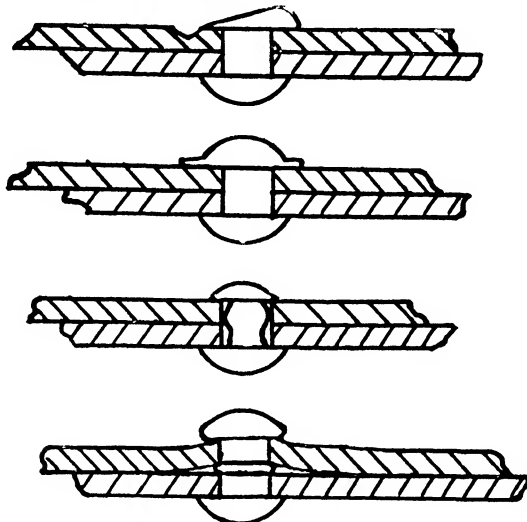
FIG. 43

Snap not struck normally to plate surface—damaged plate and weak head. Rivet too long—damaged plate and rivet. Hole too large—poor head and probable leakage. Plates not held together —deformed shank, weak joint

STREAMLINE WIRES

These wires are rolled by the makers to the required section from a diameter of round wire, which will permit of the ends being screwed to within the limits laid down in the specification. They should always be properly released and provided with a special clip on the streamline portion of the wire on which is impressed the size of the wire and the approved inspection stamp. The presence of this identification clip is highly important, because if it is removed due to any cause whatsoever, and there is no positive evidence that the wire has been satisfactorily inspected, it must be scrapped. Recent practice is to impress size and stamp at the end of the wire, thus avoiding the use of the clip.

At all times when dealing with streamline wires a very careful check should be made that there are no cracks or nicks, because, being of a very high tensile steel, there is every chance of such a crack or nick starting a fracture of the wire.

The above remarks apply in a similar manner to tie-rods, with the exception that these wires are not rolled, but swaged.

TIGHTENING OF NUTS

Too much attention cannot be given to the care required when carrying out the apparently simple operations of tightening nuts, locknuts and threaded parts. The results of either overtightening or undertightening are equally serious. The former may damage or strip the threads, rendering the parts concerned unfit for good service, while the latter results in ill-fitting or badly bedding parts, and possibly leading to a serious breakdown.

B.S. Specification No. 192/1924 and Addenda of May 1927 lays down appropriate lengths of spanners for the various sizes of studs and bolts. The following list selected from this Specification is added for guidance—

Diameter of Bolt	Length of Single-ended Spanner	
	B.S.W.	B.S.F.
¼ in.	5 in.	3¼ in.
⅜ in.	6 in.	5 in.
½ in.	8 in.	6 in.
⅝ in.	9 in.	8 in.
¾ in.	10 in.	9 in.
1 in.	15 in.	12 in.

Exception should be taken to the use of ill-fitting spanners and tools generally, in consequence of the damage often caused thereby.

IDENTIFICATION OF RIVETS

The methods of ensuring that rivets of the correct material have been used are various, but the inspector should ensure that any method adopted is foolproof, and should be able to guarantee, for instance, that aluminium rivets have not been used where those of a stronger material are demanded.

For guidance in the cases of light-alloy rivets, those of aluminium could be left uncoloured, while those of alloy variety could each be distinctively coloured by dyeing the anodic film.

Stainless-steel rivets may be distinguished from those of mild steel in that the latter are cadmium-coated. Magnetic qualities will distinguish ferrous and non-ferrous rivets.

COMPONENTS

Considering a mainplane of composite construction, that is, a plane of which the chief structural members, such as spars, ribs, etc., are made of timber, and the securing fittings and bracings, etc., are of metal, the remarks regarding the quality of timber detailed in "Non-metallic Materials" at the beginning of this volume are generally applicable to all such components.

For the purposes of inspection, an uncovered main plane is placed with the spars resting on approximately level trestles, and each bay is trammelled in the manner already described, commencing at the attachment ends of the spars. Both spars should be out of winding and straight within the following limits—

A spar having a vertical bow which is smooth and regular throughout the spar length, and at right angles to the plane of the component, may be accepted, provided—

1. That the maximum amount of bow does not exceed ⅜ in.

2. That only a slight hand pressure applied to the spar is sufficient temporarily to take out the bow.

3. That the bow is such that it will rig out during erection of the component without undue stresses having to be applied during rigging. (By "rigging out" is implied that after erection and rigging the bow must not exceed 1-600th of the length between the points of strut support.)

4. That the timber is not hard-grained or otherwise defective.

A slight horizontal bow in a main spar is permissible, providing it is a regular bow and not due to hard-grained or otherwise defective timber. Further, in consequence of the horizontal bow, no undue stresses are to be imposed on the adjacent details such as ribs and bracing wires. The interchangeability of the component should also remain unaffected.

A spar showing local bowing or twisting in any direction should not be accepted for service.

Ribs must be checked for security of attachments; the crushing of timber members under washers and fittings should be carefully avoided. Adequate clearance must be allowed between bracing wires and rib members, so that no rubbing or chattering takes place. Cases are on record in which bracing wires have been worn at least half-way through due to vibration against wooden rib members.

The aileron hinges should be carefully checked for alignment and positioning. When slats are to be fitted, the attachment fittings should be so positioned that the slats will function satisfactorily in the air, and bed satisfactorily when not in use.

The fittings for attachment of the mainplane to the fuselage or centre-section should be checked against the drawing dimensions.

The principles laid down in this section for the inspection of mainplanes, coupled with the preceding remarks, apply generally to such components as the centre-section, rudder, fin, elevators, and tailplane, with such exceptions as for the limits of bowing of spars, which cannot be allowed on the spars of components carrying hinges for mating with adjacent components. The finer limits required for the alignment and satisfactory functioning of hinges ensure that the spars to which the hinges are fitted cannot be anything but reasonably straight.

All-metal components are also inspected in like manner to the composite components. The question of spar assembly requires special attention to riveting and the ultimate straightness of the spar. The question of any excess limits of bow for all-metal spars, as allowed in the case of wooden spars, must of course receive special consideration, dependent upon the design, that is beyond the ordinary limit of 1-600th, because pulling the bow out of a metal component may set up shear stresses in the rivets.

When dealing with components for an aircraft, any applicable Ground Engineer Notices should be carefully perused.

Before finally stamping as approved, all parts of the component should be satisfactorily protected against corrosion, and in this connection, especially all internal parts, such as the inside of tubes, spars, etc., which should receive an adequate coating.

FUSELAGE

For the purpose of checking the alignment of a fuselage, the component is set up in its normal flying position as shown in Fig. 44, that is, level fore and aft and athwartships, in accordance with particulars given on the drawings.

Longitudinal level.

Transverse level.

Centre marks on cross struts.

Carpenter's square.

Datum line cords.
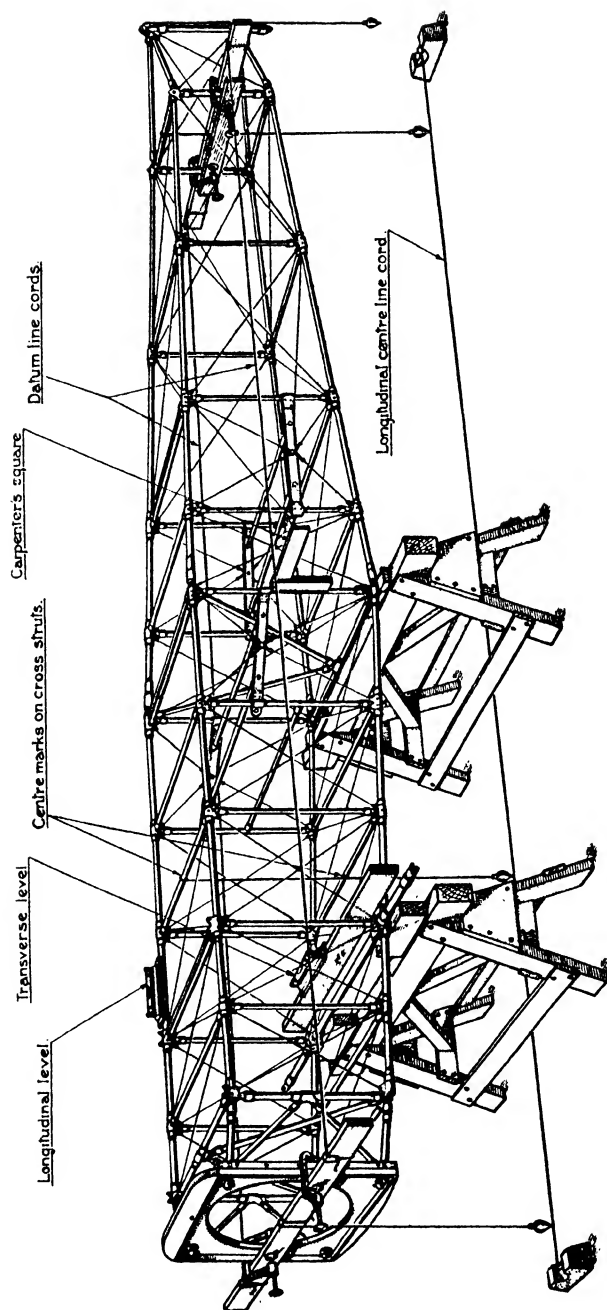
Longitudinal centre line cord.

FIG. 44

:" *Manual of Rigging for Aircraft*," *by kind permission of the Controller of His Majesty's Stationery Office*)

A cord is then attached to two weights and stretched so as to lie just above the floor, and coincident with plumblines dropped from the centre of the foremost top cross strut and the centre of the sternpost. Plumblines similarly dropped from the intermediate top cross struts coincide with the centres of the bottom cross struts and with the stretched cord. This ensures that the fuselage is symmetrically disposed about its centre-line in plan view.

The datum lines are attached symmetrically to the straight-edges at the fore and aft positions as shown in the diagram, and horizontal measurements made at either side of the fuselage should give the same readings at any vertical pair of identical side struts.

For checking that the side panels are correctly disposed measurements are made directly above and below the datum cords, squaring in from the cords where necessary.

All attachment fittings for connecting the fin, tailplane, wings, etc., should be checked while the fuselage is in this position. For instance, a board or straight-edge with suitably designed fittings attached should be tried on to the wing attachment fittings to ensure correct positioning, and that the wings will ultimately engage with the correct angle of incidence.

If the engine to be installed is of the radial type, then the engine bearer plate as shown in the diagram should be checked with the aid of plumblines and using the trammels and the spirit level at appropriate places. For squareness in plan view, diagonal measurements may be made from symmetrical points at each end of the straight-edge to identical points on each side of the fuselage.

In the case of a vertical or Vee-type engine, the bearers on the engine mounting should be checked for position both fore and aft, and athwartships, with the aid of straight-edges, which, when placed one across the aft bearers and one across the front bearers, should be level and out of winding. Similarly, when the straight-edges are placed one on the two port bearers and one on the two starboard bearers, they should again show "out of winding," and level to the designed degree.

Trammels should be used to check the positioning of the bearers with respect to the fuselage.

Inspection should then be carried out on all details and partial assemblies in the manner laid down in the earlier part of this section.

AIRSCREWS, WOODEN

Before inspecting an airscrew, definite evidence must be available that the drawing has been approved authorizing the design of the airscrew for use on the particular engine and aircraft for which it is intended.

Previous to the construction of an airscrew, the planking which is to form the laminations should be tested for compliance with the specification quoted on the airscrew drawing, and exact records of the test results obtained on each plank should be kept for future reference.

When the laminations have been cut, they should further be examined for local defects and rejected if unsatisfactory. It facilitates the work of ultimately balancing an airscrew if each lamina is checked for balance, and the heavy end marked so that the laminations, when fixed in the block, have the light and heavy ends arranged alternately.

As pointed out in the applicable timber specifications, a high moisture content is not permissible, as it is likely to cause warping of the blades after shaping, and in addition an excess of moisture affects the glued joints of an airscrew. Casein cements or cold-water glues are now in common use

for airscrew construction. Cake or jelly glues (that is "hot" glues) are not now extensively used in the manufacture of wooden airscrews, and are not recommended for use when the airscrew is to be used in tropical countries, owing to the possibility of the joints opening in the excessive heat. In the use of any cement or glue, however, it is of extreme impor-
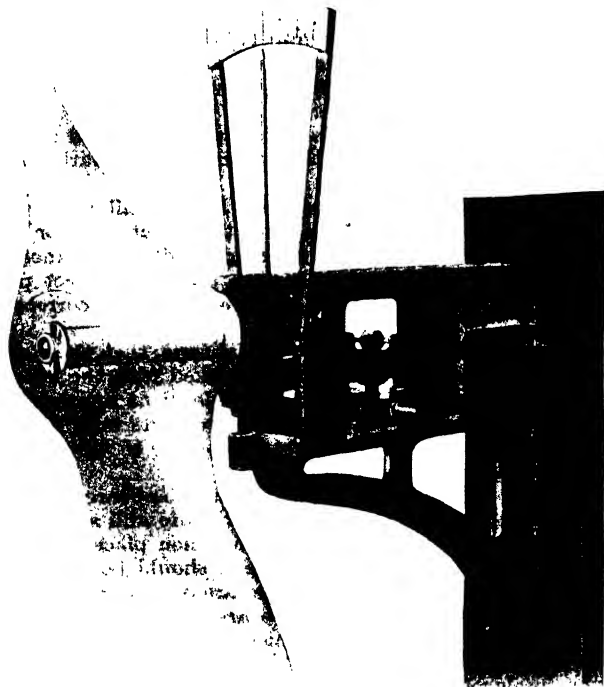
FIG. 45
(*By courtesy of W. & T. Avery, Ltd.*)

tance that the makers' instructions regarding the application are strictly adhered to.

Strict observance should be made of the prescribed waiting periods between the gluing of the different laminae, and between gluing and rough and final shaping. The actual waiting periods must be carefully recorded on the airscrew record label. When the airscrew has been finally shaped, it must be checked for balance in all positions and must be in static balance in any of these positions, including "vertical balance." Fig. 45 shows a suitable balancing machine. The balancing apparatus must be accurate to within 4 in. ounces when fully loaded.

The limits stated on the drawing for dimensions must be worked to during the construction of the airscrew, but in the absence of such limits the undermentioned may be followed—

Angles: + or – 1° over inner third of blade length; + or – ½° over outer ⅔ of blade length.

Chord width : + or – ·03 in., increasing by ·01 in. per inch of
the chord over 2 in.
Maximum thickness : + or – ·02 in. for thicknesses up to ·49 in.,
increasing by + or – ·01 in. per ½ in. of thickness above ½ in.
Diameter : + or – ·25 in.
Track : The maximum permissible error in track dimensions
is + or – ·03 in. for airscrews up to 5 ft. diameter, increasing
by + or – ·01 in. for every 2 ft. increase of diameter.

In like manner, if no limits are laid down for the boss, bore and bolt
holes, the following general limits may be worked to—

Bore : – 0 mm. to + ·5 mm.
Bolt holes : + 2 mm. to + 2·5 mm. on the nominal diameter
of the bolt.
Position of bolt holes to be within ·5 mm. of drawing require-
ments.
Distances between boss faces : + or – 2 mm.
Diameter of boss : + or – 3 mm.

The necessary protective covering and sheaths should be applied in the
manner prescribed in the drawing. In the completed stage, additional
measurements should be taken to those taken in the white, in order to
ensure that the later stages of manufacture have not caused the airscrew
to warp or cast. The airscrew should be finally balanced in its finished
state. The marking on the airscrew should be in accordance with
the particulars on the drawing. All airscrews should be inspected and
stamped at definite stages of the construction. These stages are as
follows—

1. Physical tests on timber.
2. Moisture content tests.
3. Shop storage of thicknessed boards.
4. Cement tests.
5. Laminations.
6. Mixing and application of cement.
7. Clamping periods.
8. Waiting period before rough shaping.
9. Hand of block.

1st *Inspection Stamp.*

Correctness of dimensions—
1. Waiting period before final shaping.
2. Balance.
3. Pitch angles.
4. Aerofoil sections.
5. Blade widths.
6. Blade thickness.
7. Boss dimensions and parallelism of faces.
8. Bore diameter.
9. Plan form and alignment of blades.
10. Track.
11. Size of bolt holes.
12. Position of bolt holes.

2nd *Inspection Stamp.*

Completed airscrew, including tests—
1. Protective covering.
2. Metal sheathing.

3. Filling, varnishing, painting, and general finish.
4. Final check of dimensions, including fitting of hub.
5. Marking (serial and drawing numbers, diameter, pitch, and type of engine).
6. Final balance.

   3rd Inspection Stamp.

Repaired Airscrews

The re-sheathing of an airscrew is permissible, providing that the screws and rivets bite into fresh timber. A rubbing should be taken of the old holes in the blades to ensure that the new holes for the screws and rivets are at least $\frac{1}{4}$ in. away from the existing holes.

In the case of airscrews which are subsequently repaired, an additional inspection stamp is necessary, giving an impression of the letter "R" and two numbers indicating the month and year during which the repair is carried out.

AIRSCREWS (METAL)

For the purpose of outlining the principles of metal airscrew inspection, the procedure adopted for the Fairey Reed airscrew is selected, as many of these principles will apply to a variety of types.

The Fairey Reed airscrew is made from thick duralumin sheet, and after being machined to the required shape, the blades are twisted to give the necessary pitch angles. The bosses are formed either of laminated oak or hollow aluminium castings bolted in two halves to the blades.

With the assurance of the requisite design approval, the Ground Engineer should satisfy himself regarding the materials used in construction, heat-treatments, and that all intermediate inspectional operations have been carried out and recorded.

Test specimens should be cut from the blank and carefully correlated during the initial shaping. After initial shaping, but before and for the purpose of the main twisting operation, the blanks should be heated to a temperature of 410° C. After the main twisting operation has been completed, only a slight adjustment of blade angles is permitted in the cold condition.

The blanks are then normalized at the correct temperatures and records made of the temperatures and soaking periods. Final straightening should be carried out as soon as possible after normalizing.

All test specimens should be heat-treated with the blanks and tested after ageing.

Examination for material defects should be made at all suitable stages of manufacture, to avoid the performance of unnecessary work on defective blanks.

All burrs and sharp edges should be removed after boring and drilling to avoid the possibility of the development of cracks resulting therefrom.

The bosses should be so marked with respect to their positions on the blade as to ensure correct re-assembly on any subsequent occasion.

The degree of balance and the method of balancing will be laid down in the specification or drawing, which conditions should be carefully observed.

The following sequence of operations and inspections should be carried out, and recorded before the final inspection stamp is applied—

Identification of material.
Shaping and checking of machined blank for profile, etc.
Correlating test pieces.

Nicked fracture test.
Examination for defects in material.
Heat-Treatment.
Twisting.
Normalizing.

After normalizing, blanks straightened to correct distortion caused by heat-treatment.

Proof tests of aged specimens.
Bedding of hub bosses.
Marking of hub bosses to ensure correct assembly.
Boring and drilling of bolt holes and checking correctness of these operations.

Dismantling for cleaning and radiusing of holes.
Re-assembly and preliminary balance.
Dimensional inspection.
Protective treatment.
Examination of surface for finish and defects.
Re-assembly of hub and final balance.
Identification marking.
Inspection stamp impressed or engraved for final inspection of complete airscrew.
Final stamp, for acceptance of complete airscrew for service.

All checks for dimensions, pitch angles, track, etc., should be made not less than seven days after normalizing, as within this period any of these factors may change.

Repair or reconditioning of this type of airscrew is permissible providing there are no jagged edges or cracks, and any bends are not abrupt. Further, that softening and normalizing are carried out appropriately before and after any straightening or bending.

A letter R should be impressed adjacent to the necessary additional inspection stamp, to identify the airscrew with repair or reconditioning.

UNDERCARRIAGE

This unit is not generally inspected in its built-up form until assembled to the fuselage, unless it is to be held as a spare, in which case it should be assembled to a jig, carrying attachment fittings representative of that part of the fuselage on which the undercarriage is mounted.

In dealing with the partial assemblies of an undercarriage the axle or axles (if it be of the split or divided axle type) are subjected to proof loads by the tube makers before delivery. Axle tubing is of a very high grade steel, and its mechanical properties may be seriously impaired, or cracks started, by the application of heat during any of the subsequent operations after delivery. The temperature during any soldering which may be necessary should never be taken above 200° C.

An inspectional test for cracks in axle tubing may be carried out by washing in paraffin and wiping dry, and covering the tube with a layer of French chalk, when, if there are cracks, they will become evident by the oozing of the paraffin.

All fitments made to the axle should be properly bedded down and have no tendency to impose undue local stresses. The gauge and diameter of an axle must always be checked before final approval.

When oleo legs are used, they should be tested for leaking and freedom of the operation of the moving parts. The open and closed lengths, together with the particulars of loading when closed, will be found on the drawing, and in this respect every leg must be tested for compliance therewith.

AIR VALVE

HYDRAULIC RAM SCREW

HYDRAULIC RAM PLUG

OIL LEVEL TUBE

HYDRAULIC RAM PLUG

HYDRAULIC RAM

CYLINDER

GLAND PACKING SUPPORT RING

SUSTAINING RAM HEAD

GLAND PACKING RINGS

OIL LEVEL PLUG

HYDRAULIC RAM PIN

RETURN VALVE PLATE

LOCKING PLATE

BUFFER RING

INSTRUCTION PLATE

FELT RING

SUSTAINING RAM

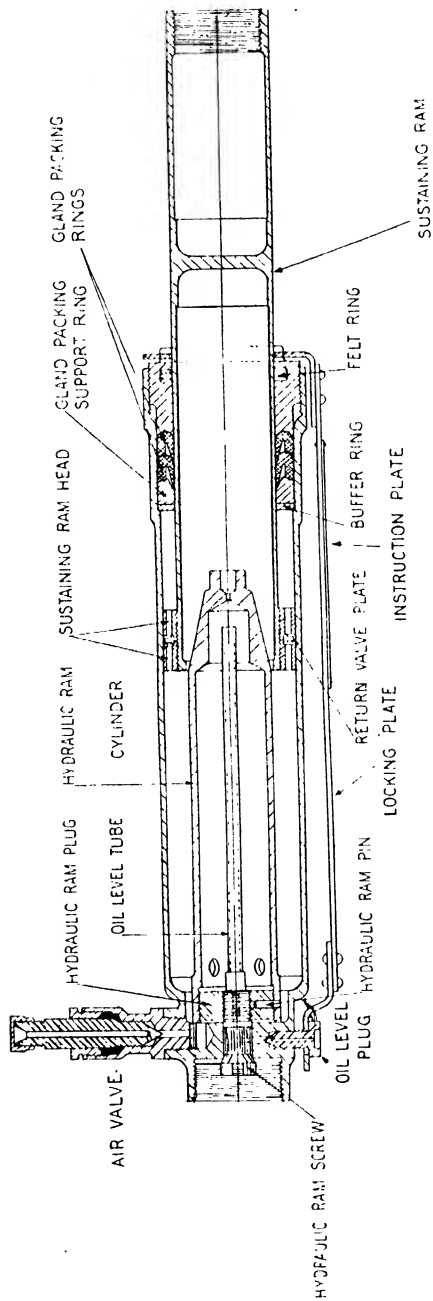Fig. 45a

OLEO LEGS

Oleo legs are of various types, but the majority are dependent for functioning on air and oil under pressure. There are also types which, in addition to the oleo portion of the strut, have steel or rubber springing arrangements. Hereunder will be found a brief description of the construction and functioning of the Vickers Ltd. Oleo-pneumatic shock-absorber struts, which are standard fitments on many types of aircraft. On reference to Fig. 45A it will be seen that this type of strut consists essentially of an air cylinder and a piston, the working gland between the piston and the cylinder being oil-sealed to prevent air leakage. The compressed air forms the springing medium, and there is an internal oil brake and rebound damper which dissipates the energy of landing and damps out oscillations.

The air pressure suitable for any particular type of aircraft may be determined by calculation when the load on the strut under static conditions is known. This is checked by the behaviour of the piston when taxying tests are being carried out. If the pressure is too low, the piston will move in too far, causing the machine to roll laterally, while if the pressure is too high, the undercarriage will be harsh and unyielding.

The machine should always be jacked up with its wheels clear of the ground before any adjustments are made to air pressure or oil level. The important requirements on the instruction plate should always be carefully observed if satisfactory functioning is to be obtained.

Air pressure may be supplied by a pump at a pressure of 800 lbs. per sq. inch, or from a compressed air bottle.

Oil level may be checked by releasing the oil valve up to half a turn and allowing the excess oil to blow off. If only air escapes, a low oil level is indicated, and a fresh supply of oil should be pumped into the strut. This check should be made preferably with the air pressure not lower than 100 lb./sq. in. and should never be carried out immediately after flight while the air and oil are in the form of an emulsion.

In describing the functioning of this type of oleo strut there are two movements of the piston to consider. Firstly the upward movement which occurs when the weight of the aircraft is taken in landing, and secondly, the downward and outward movement when the machine becomes air borne and all external load removed from the strut.

Reference to Fig. 45B will make clear the internal operations during these two movements.

As the piston is forced inwards, the oil is forcibly ejected between the Hydraulic Ram and the piston into the air cylinder. The velocity of the oil through this relatively small area is very great, and gives rise to a high pressure in the chamber with a resultant retarding effect on the piston. The oil brake converts the excess energy of the landing into heat. This heat appears in the oil, and is immediately dissipated by radiation from the exterior of the oleo strut.

The outward movement of the piston is controlled by an oil dashpot in the following manner. It will be noted that as the piston moves inwards, oil flows freely into the annular space between the piston head and the lower part of the cylinder, by way of the holes in the piston head and around the plate valve which is suspended in the piston head.

This plate valve closes and traps the oil as the piston moves on its outward travel so that the rate of return of the piston is controlled by the oil passing back, through a small hole in the plate valve, to the air chamber. The return speed of the piston is sufficient to enable the wheels to meet the recurring shocks in taxying, but not sufficiently great to cause bouncing.

As a guide that the oleo strut is in a satisfactory working condition when installed on the aircraft, it is usual to paint a coloured band on the strut fairing indicating the partially closed position of the strut when taking its machine load under static conditions. If the strut closes beyond this position, it is a clear indication that something is wrong.

Regarding inspection, the accuracy with which the detail parts are machined and fitted is of great importance. Adherence to the drawing
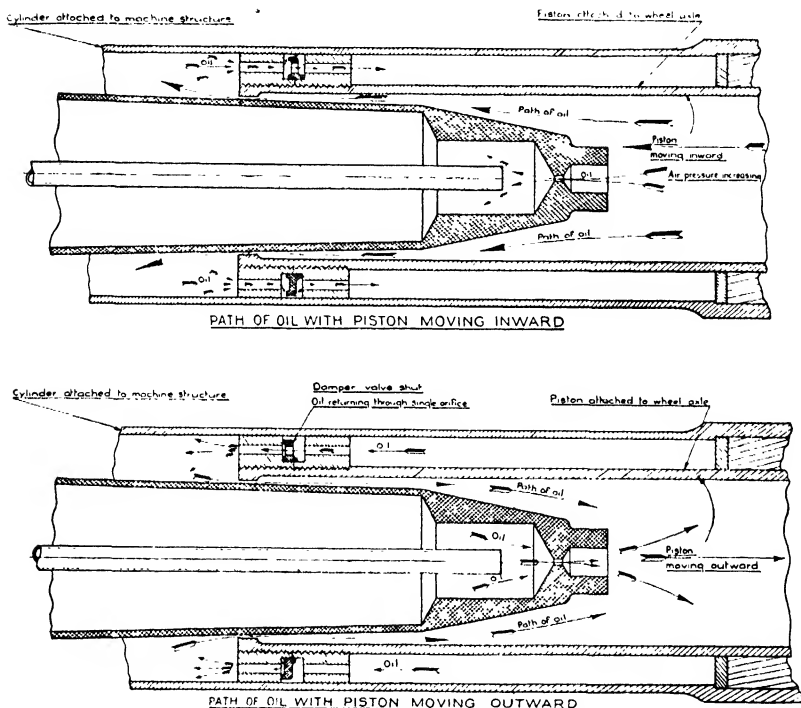
FIG. 45B. DIAGRAMS SHOWING PATH OF OIL DURING TRAVEL

limits should be carefully maintained, as any departure therefrom may cause a breakdown after assembly, together with the lengthy job of dismantling.

After assembly the strut should be pressure-tested in its completed state, and checked to ensure that the moving parts have not distorted due to the application of pressure, special attention being paid to the diameter of the sustaining ram, distortion of which would cause unsatisfactory functioning.

When streamline wires are used for bracing they should be re-examined for condition, notwithstanding that they carry evidence of normal inspection, because of the extremely important function they fill in the landing of the aircraft.

Straining cable is frequently used, and when made up for attachment to the end anchorage, is bent round a thimble to form an eye. The remaining portion of the doubled-over cable is then bound on to the cable itself

with bands of approved wire spaced at intervals as indicated on the drawing. The binding and the intervening portions of the cable forming the complete splice should then be soldered, with every care that the soldering is efficiently carried out. The cable so made up should stand up to 100 per cent of the strength of the unspliced cable.

Rubber is applied in various forms as a shock-absorbing device for undercarriage legs, and the method of determining its length of serviceable life is that of careful periodic examination, during which measurements
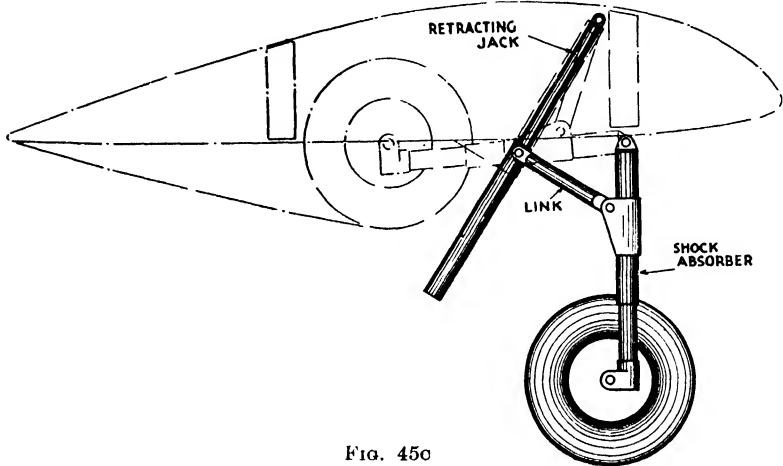

FIG. 45c

should be taken checking the necessary dimensions in the loaded and unloaded conditions.

Landing wheels are always of a specified size and type, and any substitution should only be made after the necessary design authority has been obtained.

RETRACTABLE UNDERCARRIAGES

This type of landing gear is now embodied in the design of quite a number of modern aircraft, and while it improves the speed performance of these aircraft, it adds to the responsibilities of the Ground Engineer.

Fig. 45c illustrates one type of the Dowty retracting unit as manufactured by Aircraft Components Ltd., while Figs. 45D and 45E show views of the Dowty Patent "Nutcracker" Strut for undercarriage retraction as made by the same firm. With the former, when operating, the landing wheel moves rearwards in a fore and aft line to its retracted position, indicated by chain lines, while in the latter, the wheel moves inwards athwartships to its retracted position (Fig. 45E), and can be arranged to embed completely in the under part of the fuselage, reducing drag to a still further extent. These particular units are operated hydraulically by hand or power. Hydraulically operated locks may be incorporated to hold the undercarriage in all intermediate positions, thereby preventing a collapse of the unit if a landing be made with the locking gear not right "home."

A particularly interesting type of hydraulically operated retractable undercarriage is that used on the "Ensign" type of aircraft (Armstrong Whitworth), in which the Lockheed hydraulic system is incorporated.

Fig. 45F shows the undercarriage in the down position, while Fig. 45G shows the up or retracted position. This component normally functions by the pilot using a lever operating a selector valve, which applies hydraulic pressure to the undercarriage jacks. In case of emergency,

Locked in Landing
Position

Dowty
Patent 'Nutcracker' Strut
for Undercarriage retraction

FIG. 45D

Dowty 'Nutcracker'
Type Undercarriage
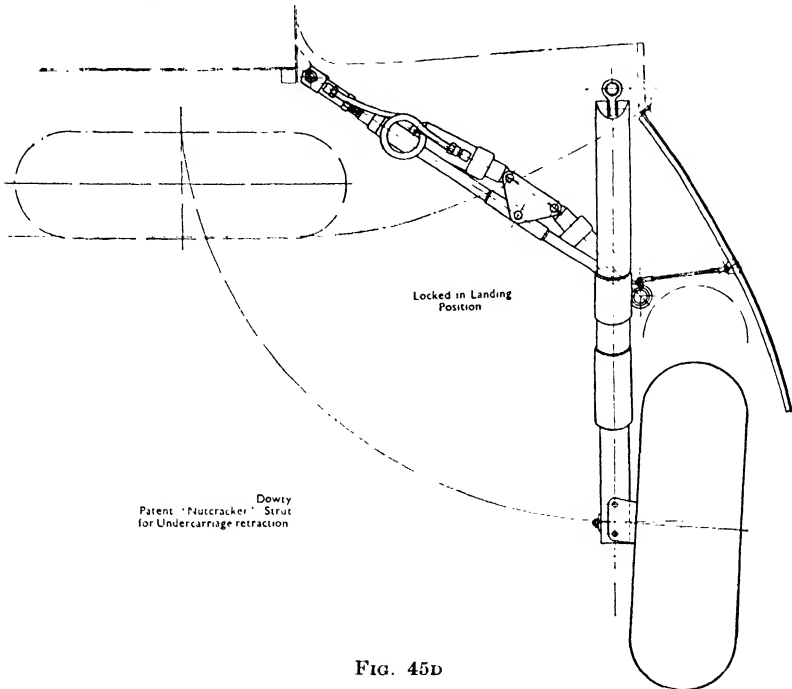
Fully Retracted.
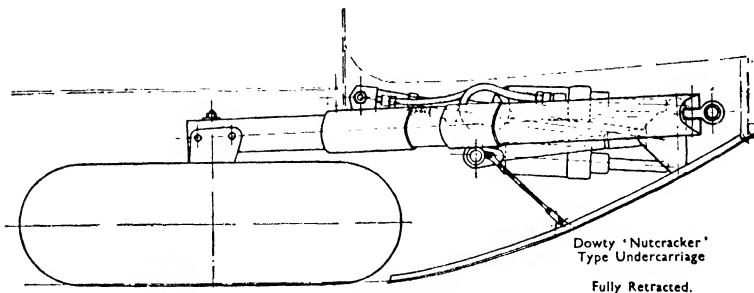
FIG. 45E

that is, if for any reason the pressure fails, the undercarriage may be lowered mechanically by a hand turning device situated in an accessible position in the fuselage.

Whatever type of retracting gear is fitted, after the normal inspection for accuracy of details and assembly, it is essential for the aircraft to be jacked up with the wheels clear of the ground, and the undercarriage retracted a number of times to ensure satisfactory functioning. The pilot's

FIG. 45F

FIG. 45G

TO TIGHTEN, TURN ECCENTRIC IN DIRECTION OF ROTATION OF WHEEL

B

D

E

FORWARD ROTATION OF WHEEL

FULCRUM PIN

SHOE TIP

CAM BLOCK

SECONDARY SHOE

TO EXPAND SHOES MOVE HAND TOWARDS AXLE

FORWARD ROTATION OF WHEEL

PRIMARY SHOE

A

Fig. 46

(By courtesy of Bendix, Ltd.)

warning indicators, showing whether the undercarriage is in the retracted or in the down position, should register correctly during these operations.

If wheel brakes are fitted, the retracting unit should be closely examined while the brakes are being torque tested, to observe specially the nature of the reaction of brake effect on the unit.

The controls should be positive in movement, easy in action, and it should not be possible for them to be put into operation accidentally.
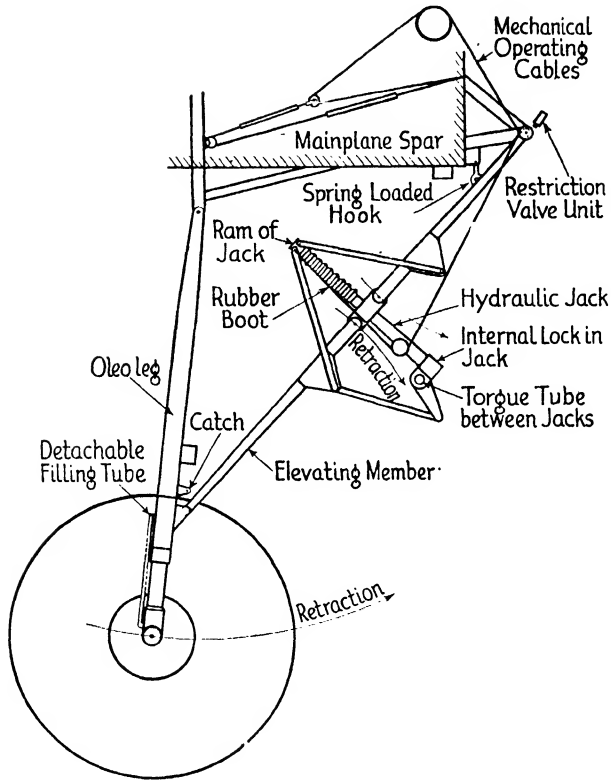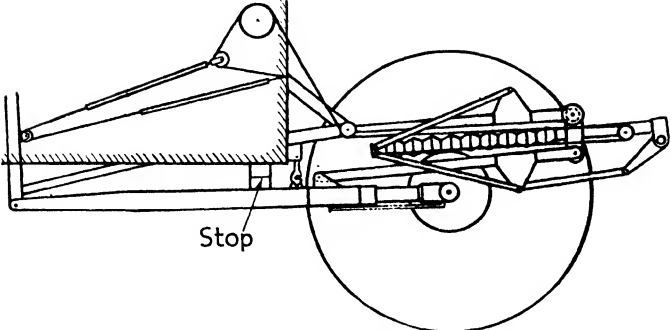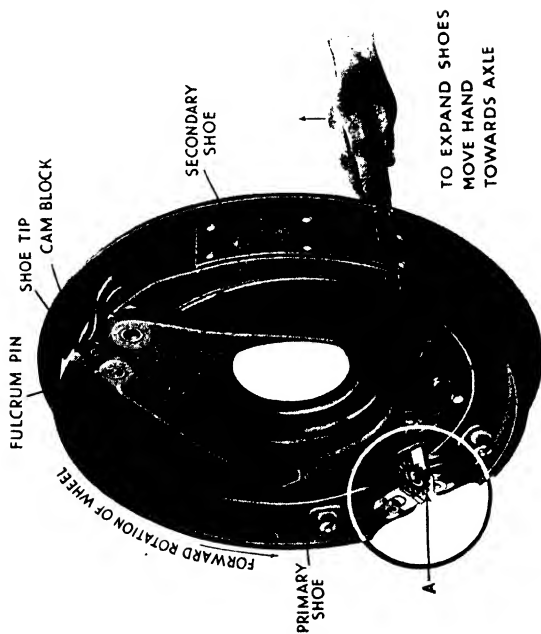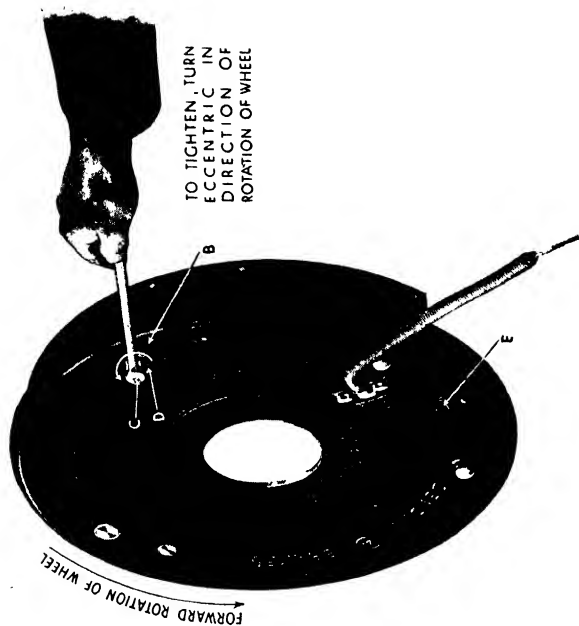
BRAKES

Wheel brakes are now being used on various types of aircraft. Three different kinds of brakes are described in the following paragraphs.

The Bendix Aircraft brake consists of two shoes, primary and secondary, which, when the brake is in operation, are expanded against the inner
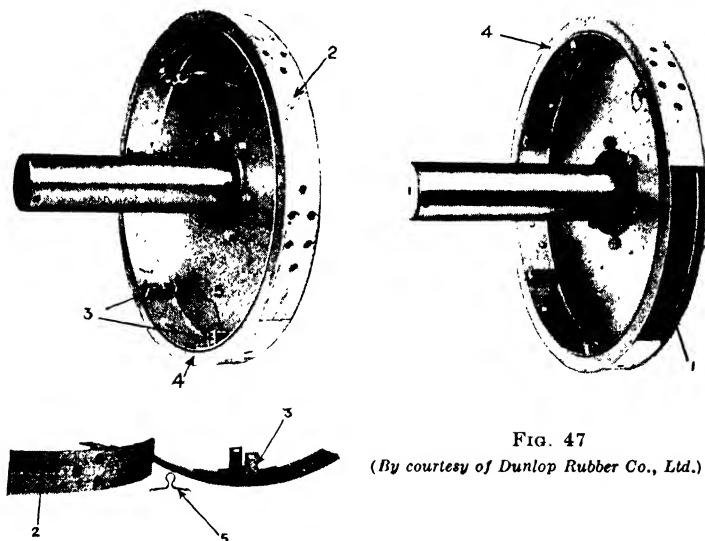
Fig. 47

(*By courtesy of Dunlop Rubber Co., Ltd.*)

periphery of the brake drum which is attached to and rotates with the aircraft wheel.

The primary shoe is in contact with the cam block of the operating lever at one end, and is hinged at the other to the lower end of the secondary shoe. The other end of the secondary shoe is anchored to the brake back plate.

The hinged connection between the two brake shoes provides a means of adjustment, and consists in effect of a turnbuckle, the inner portion of which is enlarged to form a star wheel *A* (see Fig. 46). When the brake is "off," the cam block on the end of the lever just makes contact with the primary shoe tip when the latter is resting on the fulcrum pin of the operating lever.

To adjust the secondary shoe, move the eccentric *B* in the same direction as that in which the wheel rotates, until the brake just rubs, then ease the eccentric gradually until the drum revolves freely. The primary shoe is then adjusted by means of the star wheel *A* until it just rubs, then slackened off until quite free. Both brakes should be so adjusted as to give the same resistance, for which purpose the brakes should be applied

FIG. 48

(By courtesy of Dunlop Rubber Co., Ltd.)

by means of the hand lever or toe pedals. It is considered advisable to replace a complete shoe if relining becomes necessary.

Adjustment for wear on the brake linings should always be carried out by adjusting the brake shoes as already indicated, and never by adjusting the cables.

The operating cables are, of course, adjusted to take up all slack. They should not be so tightly adjusted that they are tensioned, and the adjustment should be the same on each side.

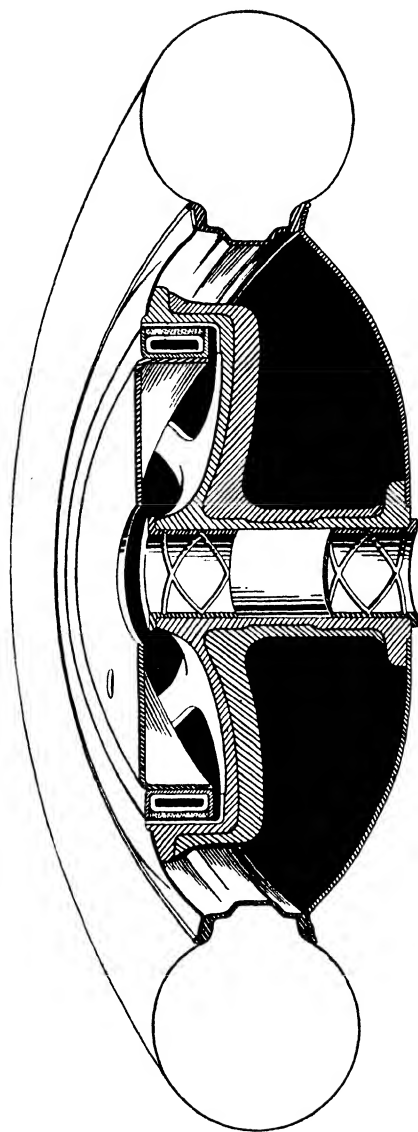The various working parts are lubricated during the assembly of the brake, and no further lubrication should be necessary between periodic overhauls of the machine, except in the case of cables, for which a special grease-gun is supplied.

Whenever the cables are lubricated, the wheels of the aircraft should be removed so as to ensure that whatever grease is forced out of the end of the cable is wiped off and not allowed to get on the shoes. It is also important that no grease is allowed to accumulate on the brake linings or the drum.

Dunlop Brake Gear

Fig. 47 shows the details of the Dunlop wheel brake unit. It consists of an annular expansion chamber (1), which, when inflated, presses the brake blocks (2) radially outwards against the brake drum of the wheel. The blocks are prevented from rotating partly by friction between the blocks and the air-bag, and partly by the clips (3) which pass through slots in the annular U-ring (4). The springs (5) positively return the brake blocks to the "off" position when it is desired to release the brake.

In Fig. 48 will be seen a half section of the wheel, including the brake. The distinctly novel dual relay valve ensures differential operation of the brakes by connection to the rudder bar or pedals, although the brakes are entirely controlled by one separate hand lever.

Whilst the rudder control is in the "dead ahead" position, the braking effect is equal on each wheel and the degree of braking can be delicately controlled by the hand lever. The physical effort required to operate this lever is small and can be compared with the pull required to operate a motor-cycle clutch.

As the rudder control is moved to steer the craft to the left or right, the braking effect is steadily increased on the inside and decreased on the outside wheel, until in the extreme position of the rudder the brake is entirely released on the outside and any degree of braking desired by the pilot can be obtained on the inside wheel by the operation of the hand control.

Palmer Aero Brake

The operation of this brake may be either by pneumatic or hydraulic pressure, and in each case there are the numerous optional methods of control. The general principle of the Palmer wheel brake will be understood after studying Figs. 49 and 50, with the added footnotes.

Taking for example the hydraulic type of pedal-operated brake, a layout diagram is shown in Fig. 51. The brakes can be applied by means of two small pumping cylinders which are mounted on the rudder bar in such positions as to allow of easy operation with the toe or heel. Each cylinder is connected with its respective wheel brake, while both are fed from one common adjustable reservoir which may be fitted to any convenient part of the structure.
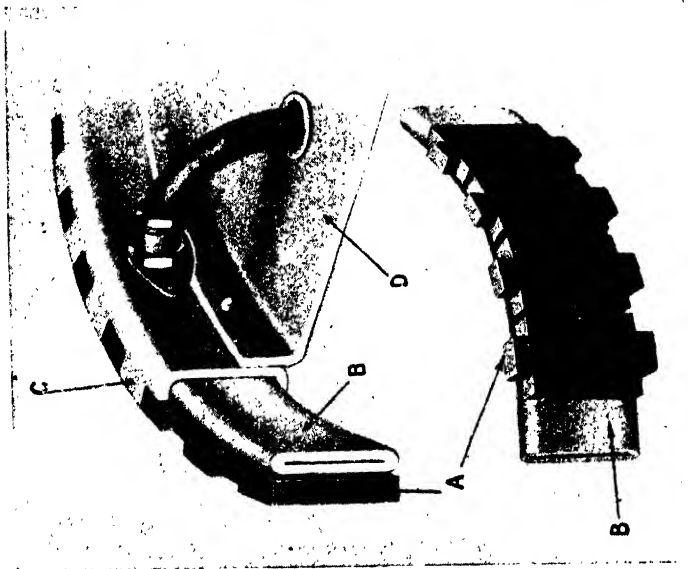
FIG. 49

The brake liner consists of the expansion chamber (B) carrying the friction blocks (A). The castellated channel (C) is attached to the cupped torque disc (D). Should the brake blocks become worn they can easily be renewed by removing the brake liner and replacing with a new one

(By courtesy of Palmer Tyre, Ltd.)
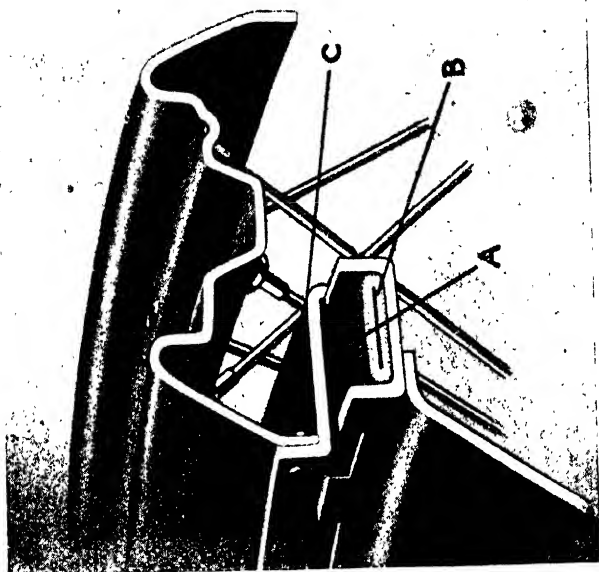
FIG. 50

When air or fluid is forced into the chamber (B), this expands and brings the blocks (A) into frictional contact with the revolving drum (C). The castellated channel prevents the friction blocks from revolving with (C)

(By courtesy of Palmer Tyre, Ltd.)

FIG. 51

(By courtesy of Palmer Tyre, Ltd.)
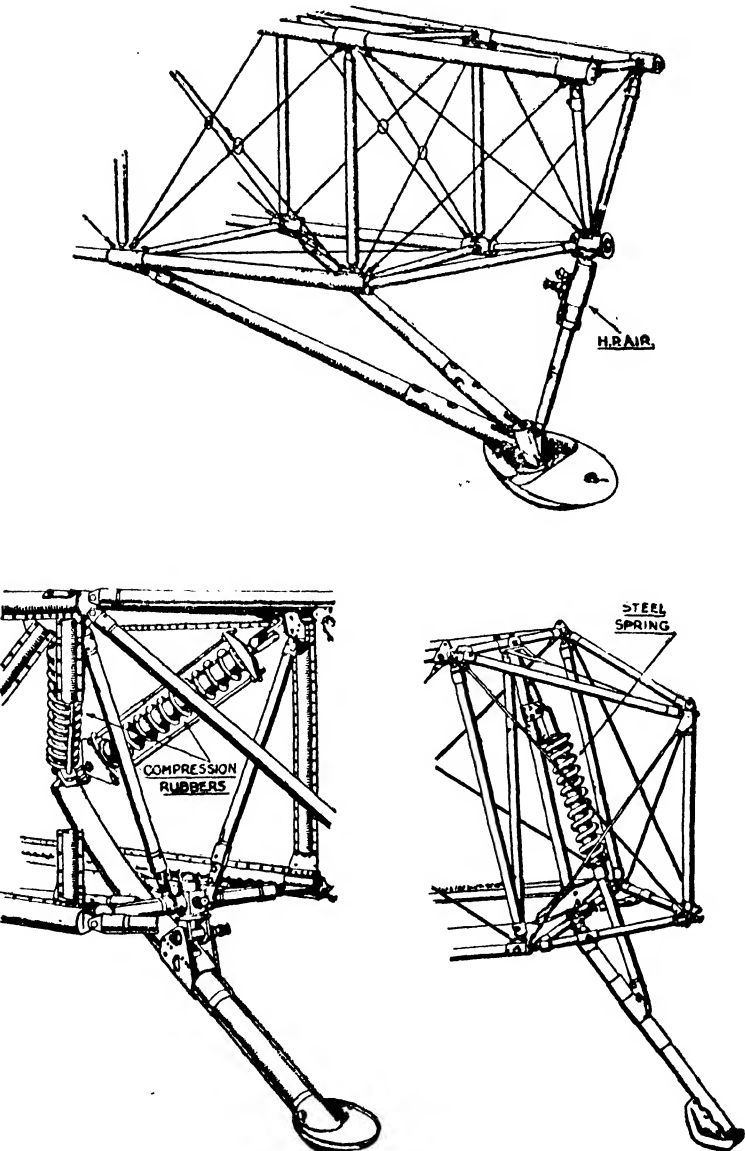
FIG. 51A

The plungers are supplied in pairs, right-handed and left-handed. When priming this system it is essential that the foot-pedals be turned with the nozzles uppermost to ensure that as the fluid is forced in all air will be expelled. If the pedals are left in position they will only be about one-third filled with fluid and the brake will not function.

The method of operation of the parking control is to apply both brakes firmly with the pedals and then switch over the parking control to the "locked" position. This maintains the pressure in the brakes while the pedals remain down after the feet have been removed until such time as the parking switch is turned to "off."

The "parking" switch can be mounted in any convenient place in the cockpit to enable the pilot to lock the brakes in the "on" position when desired.

The action of aircraft brakes should be progressive, and should cease to act on removal of the controlling force. If of the pressure type, the system should be checked for leaks while under pressure. All parts should be inspected in detail, and for final functioning of the brakes a torque test may be applied as described under "Completed Aircraft."

TAIL SKIDS

This component usually consists of the single lever design with steel springs, rubber shock absorbers in compression or tension, or an oleo strut to absorb the shock of the tail landing. Fig. 51A illustrates three different types. A skid shoe of hard-wearing metal, or a tail wheel, is fitted at the lower end of the lever.

The shock-absorbing unit should be independently checked for correct functioning previously to assembly.

If the tail skid has been in service, its parts should be examined for damage, fracture, wear and buckling or bending of tubular members.

INSPECTION OF PETROL, OIL, AND WATER TANKS

All materials used in the construction of tanks must have been properly covered with approved Release Notes, and must comply with the specifications called for on the tank drawing.

Fig. 52 shows a typical joint for connecting the end to the shell of a tinned steel, brass, or copper tank.

With aluminium tanks. it is common practice to weld the joints, and Fig. 53 illustrates the sections of typical joints.

An important stage of inspection is that of a tank submitted before closing the interior by means of the sealing end, and at this stage the whole of the interior of the tank should be carefully inspected. It is important to examine the riveting, that all the sharp edges from baffles, etc., have been removed, and the flanges and fittings at the apertures have been finished off satisfactorily.

It is general in aircraft construction to prohibit incisions or such marks as are made by scriber points, and the

FIG. 52

observation of this ruling is most essential in the construction of tanks.

The pressure test is next carried out at a pressure stated on the drawing, or, failing this, the pressure laid down in the relevant inspection leaflet.
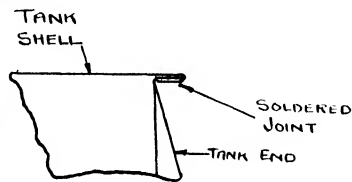
For this purpose a quantity of paraffin, equal to one-tenth capacity of of the tank, is inserted, and all apertures adequately sealed, and the required pressure applied to the tank. While the pressure is still applied, the tank should be moved about in all positions so that in turn the paraffin touches all possible parts of the shell, when, if the tank is not sound, the leak will be easily seen by traces of paraffin on the outside. It assists detection if the joints and all important connections on the tank are coated with some such material as whitening.

An alternative and accurate method of testing a tank up to the requisite pressure when a pressure gauge is not available, is to fill the tank completely with paraffin and apply a head of paraffin equal to the pressure demanded by the drawings. An easy method of applying a head is to drill a hole in a filler cap and fit into it a length of metal tubing of a suitable diameter (say $\frac{1}{4}$ in.) so that the tube is vertical when the filler cap is fitted to the tank inlet. The tube may be cut off to the length required and the paraffin poured into it carefully to avoid any possibility of an air lock. See Fig. 53A.
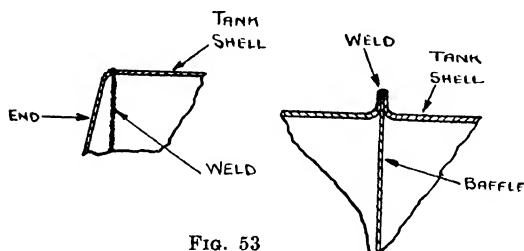
FIG. 53

After the completion of a tank, it must be washed thoroughly with hot water to remove any dirt or foreign matter, and all traces of the soldering flux, which, if allowed to remain, causes rapid corrosion. Such washing must be followed by efficiently drying the tank.

The capacity of a tank carrying more than 10 gal. should be within plus or minus 2 per cent of that specified, and not less than minus 2 per cent of the capacity specified in the case of tanks of under 10 gal.

The capacity marked on oil tanks should always allow for the specified air space. The Design Leaflet lays down that the filler must be so located that sufficient air space is left and an adequate vent provided.

An inspector should not stamp a tank as approved until he is satisfied that all standard rulings have been complied with and that the tank conforms to the applicable drawings and specifications.

DE BERGUE RIVETED TANKS

Many petrol, oil and water tanks are now constructed from light alloys such as duralumin and alclad, in which the joints are formed by the De Bergue Patent Countersunk Riveting process.

Here it should be noted that welding the joints of duralumin and alclad tanks is not an accepted practice, as the temperatures necessary for welding embrittle the metal in the vicinity of the weld to a dangerous extent. Subsequent heat-treatment will not remove the effect of this brittleness.

Initially the joint is formed, and the holes drilled, in a manner similarly to the ordinary riveted joint.

The riveting is performed on a specially designed pneumatic squeeze riveting machine. The gap of the machine is usually arranged vertically, and operated by a treadle so that the operator has the freedom of both hands, for manipulating the jointed plates on the tanks.
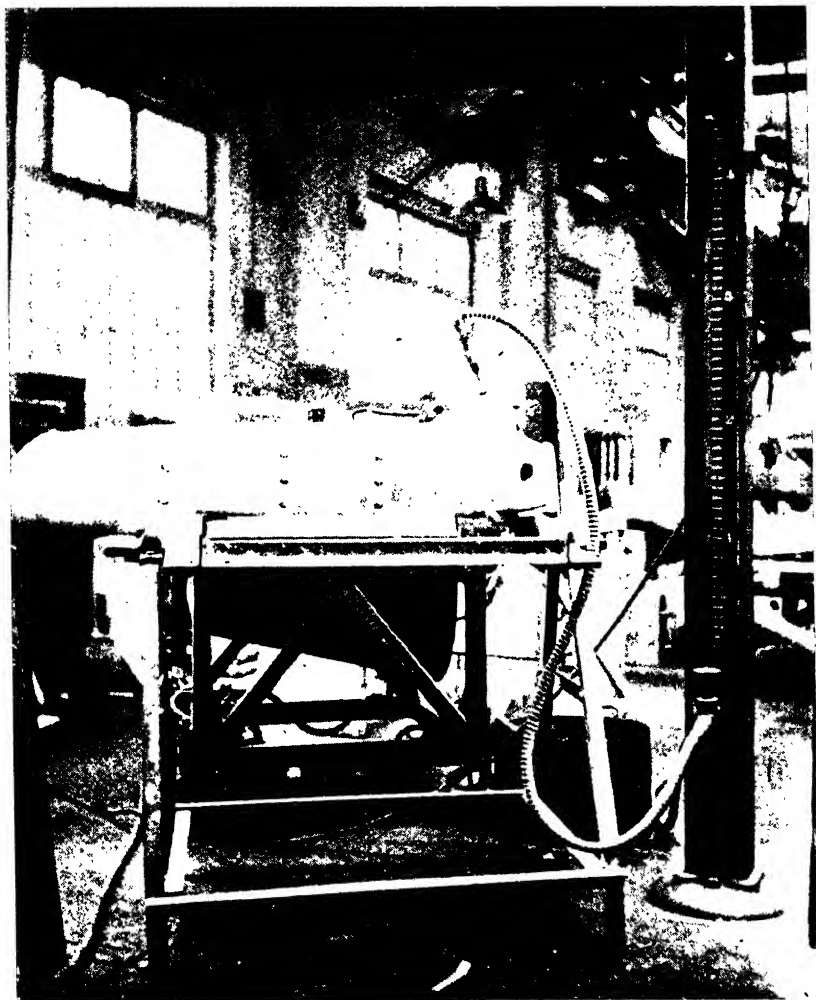
Fig. 53a

Fig. 53B shows a section of part of a joint before and after riveting.

The Jointing material may be thin rubber proofed fabric or any material specially approved for the purpose.

In the case of rivets becoming leaky through the tank being damaged, they may be replaced by new rivets $_{3}^{1}{}_{2}$ in. larger in shank diameter than the original rivets, but with the same size head as the original rivets.

If re-riveting is impossible through inaccessibility, as in the case of tank baffles fixed to the shell by this process, a screwed bolt suitably washered may be employed. A washer of similar material to that used for the jointing should be employed under the metal washer.

FIG. 53B

The method of examination of tanks constructed by this process follows the usual methods laid down herein.

RADIATORS

Before proceeding with the final inspection of radiators, it is most essential that the processes involved in the manufacture have been carried out satisfactorily.

All soft-solder used in the construction is that known as Grade "B," which has approximately 50 per cent tin and 50 per cent lead, and has a higher melting point than Grade "A" solder, with approximately 65 per cent tin. The melting point of the former is approximately 205° C., and of the latter 180° C. The object of this ruling is that when repairs are afterwards carried out, by using Grade "A" solder there is no risk of affecting soldered joints in the locality of the repair.

All details shall have been inspected and made from approved materials, especially the radiator tubes. These tubes are manufactured from very pure brass of the following composition—

Copper, between 68 and 74 per cent.
Zinc, the remainder.
Impurities—
Lead, not more than ·05 per cent.
Iron, not more than ·05 per cent.
Bismuth, not more than ·006 per cent.
Nickel, not more than ·1 per cent.
Any other metallic impurities (excluding
  silver), not more than ·005 per cent.

Every tube, while subjected to an internal air pressure of 15 lb. per square inch, is immersed in water and must show no sign of leaking.

In the manufacture of the radiator shell and tankage, a very careful check should be made of the attachment and soldering of all suspension brackets and fittings to ensure that—

(*a*) The radiator is correctly positioned in relation to the ultimate attachment to the aircraft.

(*b*) All rivet and bolt heads on the inner side of the shell have sufficient clearance to obviate the risk of damage to the tube block during "panting" of the casing.

(*c*) All joints and rivets attaching fittings have been cleanly and sufficiently soldered.

Special care should be taken in the use of cramps whilst building the tube block, as due to their thinness the tubes may easily be distorted, and it is essential that a check of dimensions over a number of tubes be made at this stage, as the weight of solder picked up in dipping and the water-tightness of the finished block are directly governed by the spacing of the tubes. During construction all parts should be kept free from dirt or grit, or loose solder, owing to the very narrow waterways in the completed radiator, which so easily become blocked.

Just previously to dipping a tube block it is necessary to ensure that—

1. The tubes are levelled on the block faces on a surface plate.

2. The surface of the solder bath is skimmed to remove any dross, and that the flux bath is clean.

3. The solder bath temperature is correct and pyrometrically controlled.

4. The blocks are sealed to the correct depth on the tube bulges.

The analysis of the solder should be periodically checked in order to maintain consistency of composition.

Great care should be exercised during the "loading" of the casing to the tube block, to ensure that strips of solder do not penetrate beyond the swaging of the casing at the inner end of the tube bulges.

After completion, the radiator shall be tested to ensure that—

1. The dry weight is within the limits specified.

2. The capacity is as shown on the drawing.

3. It will withstand for 10 min. a pressure of 6 lb. per square inch while filled with water at 180° F. without leaking. Immediately following the removal of the hot water, the radiator shall be filled with cold water and subjected to the same pressure as above for not less than 30 min., and again show no sign of leaking.

4. The flow of water through the radiator satisfies specified requirements, while being flow tested under a constant head of 7 ft. of water, which head is measured above the radiator inlet.

The flow is measured by the quantity of water issuing from the radiator outlet. The measuring vessel should not be more than 1 ft. below the radiator outlet. The duration of the test must not be less than 20 sec. after a steady condition of flow is maintained, the time being recorded by means of a stop-watch. During the test, the radiator must be in a position similar to that which it would occupy in the aircraft.

Repairs

Before any repairs are effected on a radiator it is essential that the radiator be emptied and dried. A special degree of skill is required in effecting soldering repairs in the vicinity of the tube block, especially to prevent the ingress of solder, as an overheated soldering iron may unseal a number of tubes. To remove a leaking tube from the block a pair of

punches, which have been shaped to fit the ends of the tube, should be heated and inserted the full depth of the bulges at each end of the damaged tube. When the solder at the end of the bulges becomes fluid, the tube may be carefully pushed out of the block from one side.

If a new tube-block is necessary, after removal of the old block all traces of corrosion and foreign matter must be removed and the casing rendered as new.

In the case of a radiator requiring repair to a tube-block, no plugging of tubes is permitted, and tubes which leak at points other than soldered joints must be replaced.

After repair the necessary tests must be carried out as for new radiators.

OIL COOLERS

With the introduction of modern high-powered aero engines and the necessity of cooling such engines as much as possible, oil cooling by means of a specially designed component became inevitable.

The cooler is usually inserted between the engine scavenge pump and the oil tank, thus cooling the oil to the required degree on its return from the engine to the tank ready for re-delivery to the engine.

These coolers come within the category of aircraft components, and must follow the usual course of inspection both with regard to the details and the finished unit.

There are many different types of oil cooler, but in these pages I shall confine myself to the description and methods of inspection of the Vickers-Potts type.

As will be seen from Fig. 53c it consists of a number of hollow fins threaded on two tubes, and so arranged that the returning oil passes down to the bottom of the inlet tube, thence through each fin in turn to the outlet. Next the outlet will be seen the by-pass valve inserted between the inlet and outlet pipes for relieving the pressure when starting from the cold, and in order to avoid excessive pressures in the fins.

During assembly of the fins on the tubes, it is essential that the embossed " O "'s at one end of each fin appear in the following positions—

Top fin	.	.	.	.	. O on top
Second fin	.	.	.	.	. O on bottom
Third fin .	.	.	.	.	. O on top
Fourth fin	.	.	.	.	. O on bottom
Fifth fin .	.	.	.	.	. O on top

and so on to the completion of the unit up to a maximum of eleven fins

It is further important before finally tightening the end nuts, that the duralumin spacers are central. The following are outstanding features of inspection in addition to the normal routine inspection—

1. Each fin after completion and inspection should be tested with mineral oil at a minimum temperature of 40° C. at an internal pressure of 45 lb. per square inch. The word "tested" and a covering inspection stamp should be impressed to indicate satisfactory passing.

2. Before assembly and after normal inspection, the relief valve should be tested at an inlet pressure of 15 lb. per square inch, and the word "tested" and the inspection stamp added as for the fins.

3. A flow test on the completed cooler must be carried out with mineral oil at a temperature of not less than 40° C., the oil flowing freely through the cooler. It is important to observe that each fin warms up in correct order to indicate a satisfactory flow and correct assembly of the fins.

4. A pressure of 25 lb. per square inch should be applied while the

(Oil Cooler, Standard, Air Ministry Type A 325)

Fig. 53c
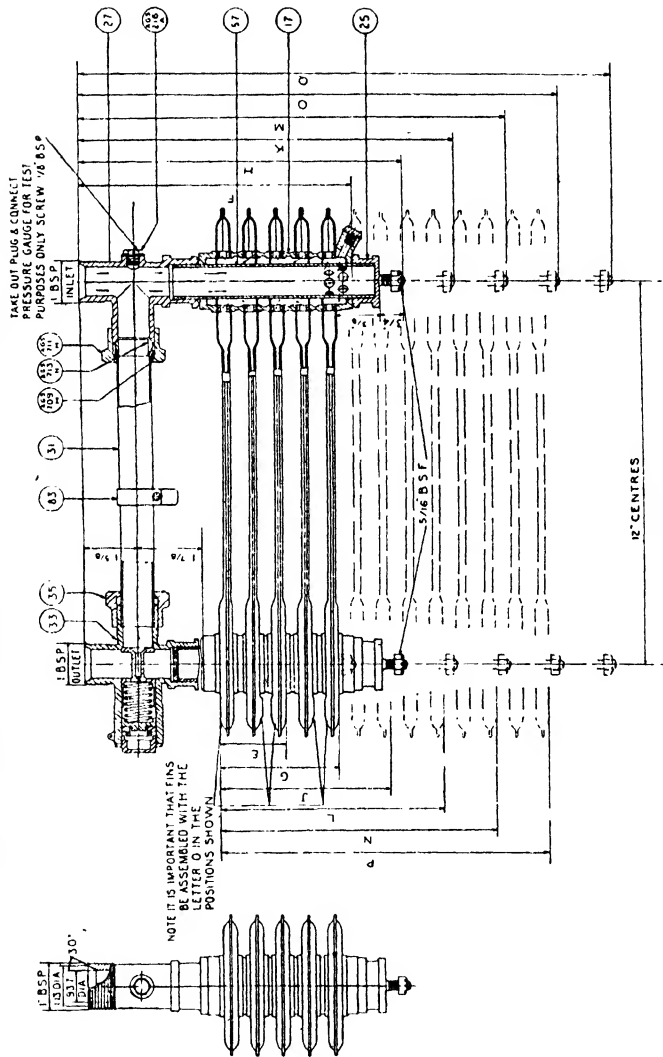
cooler is filled with hot oil, and this pressure maintained for fifteen minutes without showing any signs of leakage.

ACCESSORIES FOR PETROL, OIL, AND WATER SYSTEMS

All cocks, valves, pumps, filters, and similar assemblies, should have their detail parts independently examined, and stamped previous to assembly, and the completed article finally stamped as conforming to the drawing. Identification numbers or letters should be impressed, denoting type, etc., to avoid the incorporation of an incorrect article into any system concerned. Before finally testing such parts, they should be cleansed from all grit, solder, and any foreign matter. The writer has knowledge of the forced landing of an aircraft due to a tiny piece of cotton fibre adhering to the seating of a relief valve, and thereby putting the valve out of action. The importance of cleanliness cannot be too heavily stressed.

Testing

The specified tests for flow, pressure, etc., should be carried out on every accessory, on which should be stamped the word "TESTED," providing that they are up to the standard required.

The nature of the tests is usually specified, but in the absence of such specification and for general guidance, all petrol cocks and valves must withstand an internal pressure of 15 lb. per square inch without leakage. This test may be carried out by using paraffin internally, the castings being whitened externally, or by means of air pressure, with the cock or valve immersed in petrol or paraffin.

They should also be flow-tested under a standard head of 1 ft. Each cock or valve, when open, must pass petrol at not less than the minimum rate of gallons per hour called for on the drawing or specification. It is important that only petrol should be used for the flow test, because any other liquid will give an erroneous idea of the rate of flow obtainable.

Drain cocks with a film of oil between the plug and the body must withstand a test pressure of 15 lb. per square inch without leakage. Each petrol pump must be pressure-tested to 15 lb. per square inch and be tested for delivery capacity under conditions of speed and suction, and delivery heads applicable to the particular pump.

HULLS AND FLOATS

So far as the inspection of the flying structure of a float seaplane or of a flying boat is concerned, there is very little difference between this and the inspection of a land-plane.

The hulls and floats, however, involve different methods of inspection, especially in the early stages of construction, and, unlike a number of fuselage designs, do not allow of any readjustment in alignment when completed.

Further, while particular attention is paid to protective processes on land craft, even greater precautions are necessary in the case of sea craft, due to the intensive corrosive action of sea water and sea air, and for this reason such materials as alclad and other aluminium alloys, which are in general use (particularly on account of weight), are anodically treated as a primary protection against corrosion. Stainless steel is used for fittings, etc., but at present is not in general use for shell plating.

Details

All details from which the assembly is made or repaired must be previously inspected for compliance with the drawings, and for the observance of standard rulings with regard to protective processes, etc., and must bear evidence of this inspection.

The inspectional work should be carried out in progressive stages during construction, varying only to suit the particular design or the methods of different constructors. The satisfactory completion of these stages, which are outlined below, should be recorded on a card or chart so that when final inspection takes place, the inspector will have every assurance that previous inspections have been fully carried out.

" Lay-off " of Lines, etc.

Careful checks should be made to ensure that the "lay-off" from the scale drawing to the full size on the mould loft floor has been carried out correctly. The moulds and templates must be checked with the lines and body sections on the mould loft floor and scrieve boards. A scrieve board is one on which the various sections or half sections of a hull or float are drawn out full size, the idea of which may be gathered from Fig. 54.

The contour of each frame is to be checked to the scrieve board, while each section of the keel, keelson, and stem is checked to a profile template on to the lines laid off on the mould loft floor.

The centre and datum lines should be checked while the moulds or frame supports are inspected for position and levels. On the stocks, the assembly of such members should be checked for alignment, location, and security, including their positions relative to the centre and datum lines.

Assembly Inspection

The assembly of the framing should be inspected before the shell-plating is fitted. This stage includes the inspection of all frames for fixing and position, all internal work such as the assembly of all intercostals, ribs, stringers, etc. Levelling and datum brackets should. be carefully checked, because on these subsequent alignment so much depends.

95

Shell-plating (see Figs. 55 and 56)

The watertightness of a hull or float is dependent upon good workman-ship, and should be obtained by well-fitting seams and good riveting. The punching of rivet holes is not permitted, but drilling only. A check should be made that all holes are drilled to the correct size and pitch. Burrs should be removed from each hole and all swarf cleaned from between the fitting surfaces, to ensure that the parts come in close contact during the
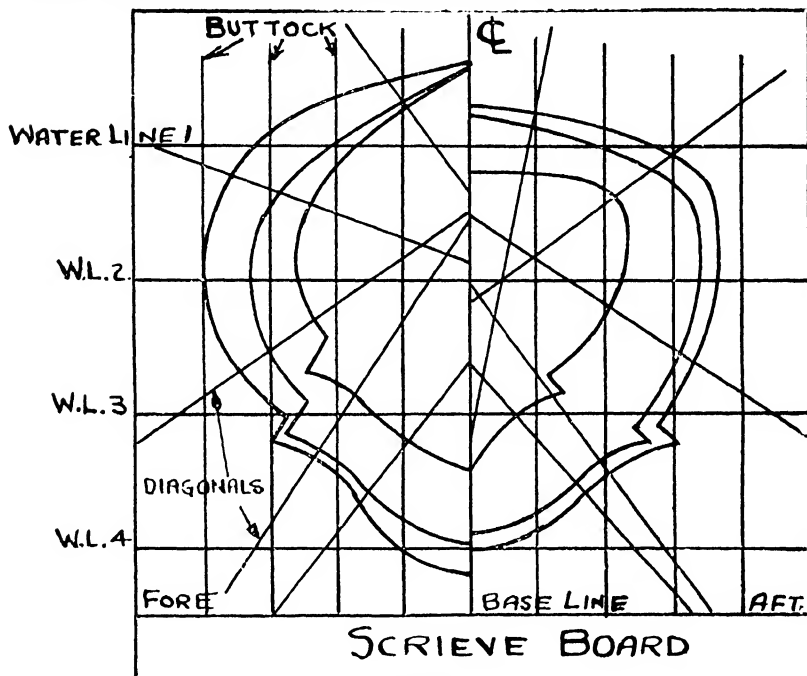
FIG. 54

process of riveting. Correct clearance should be allowed between the rivet and hole. The drifting of holes is prohibited.

All contact faces of seams and all other joints are coated with an approved jointing medium, such as a liquid marine glue, or enamel; the object of this coating being not only to provide an additional safeguard against leakage, but also a further protective coating against corrosion. The use of stopping is deprecated, and should only be used in positions such as where longitudinal and vertical seams meet, and it is difficult to make a satisfactory tight joggle.

All plating requiring anodic treatment should have this process carried out after all work, including the drilling of rivet holes, is completed, which will involve dismantling after temporarily fitting the plating.

Final Inspection

Before final inspection for alignment, which follows closely that laid down for the fuselage of a landcraft, the hull or float is to be freed from all
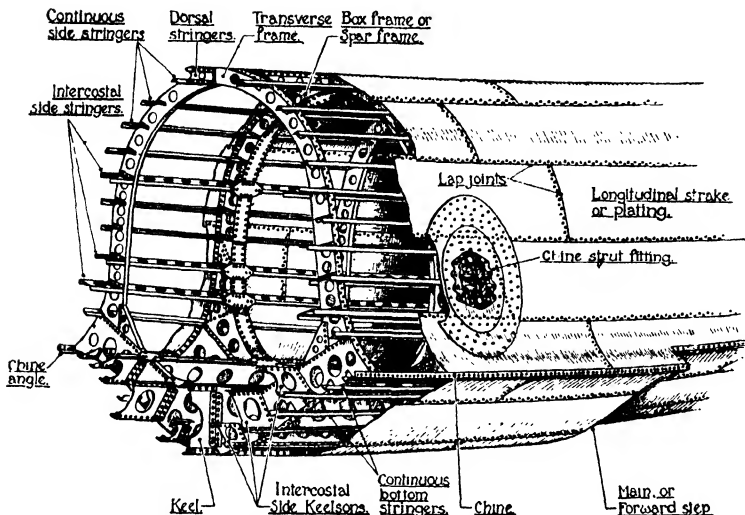
FIG. 55. LONGITUDINALLY PLATED HULL

("*Manual of Rigging for Aircraft*," *by kind permission of the Controller of His Majesty's Stationery Office*)

FIG. 56. RING PLATED HULL

("*Manual of Rigging for Aircraft*," *by kind permission of the Controller of His Majesty's Stationery Office*)

external struts and fixings which would tend to give false readings or measurements. This stage will also include the inspection of all external fittings, including those for the attachment of the other components and of the hull or float, to the superstructure. They should be examined for security and interchangeability. If no gauges are available for this latter check, resort should be made to trammels and direct measurement.
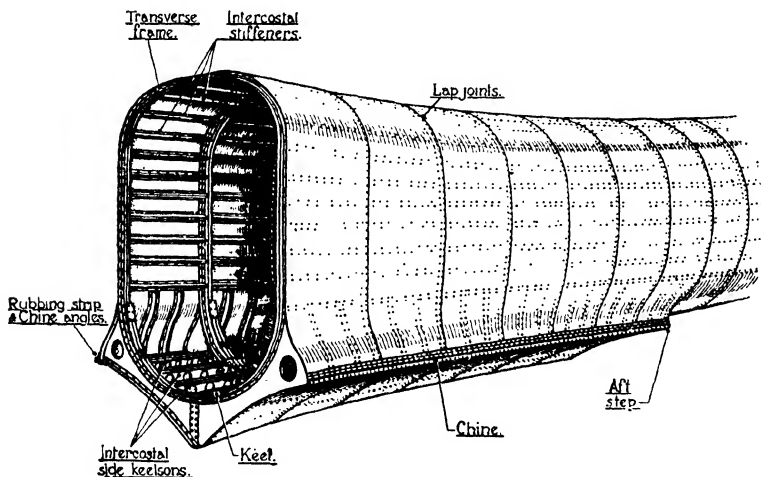
The method of testing for watertightness in the case of hulls is that of spraying water on all joints outside the hull through a hose-pipe fitted with a small nozzle, and giving a fine jet of water at high pressure. The detection of any leak will be made by examination on the inside of the component during the spraying operation.

Floats may be tested by placing a limited quantity of water inside the components, and after securing the watertight covers, the floats may be turned about so that all the joints in turn may be exposed to the water where, if any leaking takes place, it may be detected by examining the exterior of the float.

With these inspectional stages completed, final stamping will take place after examination for good finish, final protective coatings, and that the hull or float complies with the necessary drawings and specifications.

Repairs

When it becomes necessary to repair an extensively damaged hull or float, all the affected members and plating should be removed and replaced by new material in accordance with the original design.

Where structural members are only replaced in part, the conditions of an approved repair scheme should be applied, and if there is no already prepared scheme, the designing authority should be requested to furnish sketches or drawings for the repair.

Small holes in the shell-plating may be repaired by fitting a suitably sized patch of the same kind of material as the plating.

EXPLANATION OF TECHNICAL TERMS USED IN
HULL AND FLOAT CONSTRUCTION

Buttock Lines .	.	Longitudinal sections in a vertical plane.
Base Line .	.	Datum line from which all vertical dimensions are taken. The load water line is sometimes used as the datum and dimensions taken above and below.
Coamings .	.	Vertical linings to cockpits, hatchways, and other openings in decks, etc.
Chine . .	.	Longitudinal member forming a connection between plating which does not continue in a fair curve in a vertical plane, forming a break or angle at the bilge.
Centre Line .	.	Line from which all transverse dimensions are taken.
Dorsal . .	.	The member which runs fore and aft on the top centre line of the hull connecting the top of the stem and stern post.
Diagonals .	.	Longitudinal sections in planes at various angles to the vertical plane arranged to cross-section lines as near to 90° as possible, used as fairing lines.
Fairing . .	.	A process by which the intersections of curved lines with other lines in the body plan, half breadth plan, and sheer plan are made to correspond. A fair curve is a curved line which has no abrupt or unfair inflexions in its length.
False Keel .	.	A member fitted under the main keel to deepen it or fitted over plating to protect it on taking the ground.
Half Breadth Plan .	.	Half sections in an horizontal plane at water lines.
Inwales . .	.	Longitudinal members at junction of topsides and deck.

Keel . . .	Longitudinal centre member running the length of the hull or float.
Keelson . . .	An inside keel fitted over the keel and floors.
Lay Off . . .	To transfer the design of the hull or float lines from the scale drawings to full size on the mould loft floor.
Stem . . .	A continuation of the keelson at the fore-end swept up at a more abrupt curve to meet the dorsal member.
Stern Post . .	The aft vertical member between keelson and dorsal member.
Sheer Lines or Profile	Side elevation.
Sections or Body Plan	Transverse sections on a vertical plan from which the moulds, frames, etc., are made.
Water Lines . .	Longitudinal sections in an horizontal plane.

CHAPTER V

INSPECTION OF COMPLETED AIRCRAFT

BEFORE commencing the inspection of a completed aircraft the ground engineer should be in possession of, or have sufficient knowledge of, complete information regarding rigging particulars, and all the various installations which are incorporated in the type of machine he is to inspect. In the majority of cases a handbook is issued by the designing firm containing an outline of leading particulars and of points requiring special attention. Reference should also be made to any applicable Ground Engineers' Notices. That the machine conforms to the "type" aircraft is also important.

Inspection of Rigging (see Fig. 57)

For this purpose the aircraft is placed in a flying position, supported at the jacking points with the wheels and tail skid off the ground. Indications are usually given of the positions of the jacking points or blocks, which are integral with the fuselage, but in the absence of these indications care must be exercised to ensure that when the machine is lifted off the ground no damage is done to the fuselage at or near the points of support. The flying position is obtained by levelling athwartships and fore and aft with the aid of a spirit-level on the recognized datum faces, which may be the top surfaces of an appropriate fuselage cross-strut and longeron respectively.

When the machine has been levelled suitable trestles should be placed under the lower wings at or near the outer interplane struts, in such a manner that they take no load of the machine, but are there in case the machine is accidentally dislodged.

The correct setting of the centre plane or planes should be checked by hanging plumblines on each side and measuring to symmetrical points on each side of the fuselage. The incidence is checked in a manner similar to that laid down hereunder for the wings and the cross-level by means of a spirit-level on the top of the centre section in line with the front spar.

The dihedral angles of the wings should next be measured by placing a straight-edge on the top of the wing surface, and as near as possible to, and usually parallel with, the front spar, and applying an Abney level or other suitable inclinometer.

The wing incidence is measured by placing the inclinometer on the straight-edge, which is pressed against the lower surface of the wing in line with one of the ribs. Special incidence boards are sometimes necessary for this check, depending on the wing design.

The incidence angles should be checked at the root end of each wing, and at the interplane strut fittings. The wing and thereby the centre plane stagger is checked by hanging plumblines over the leading edges of the top planes and taking the dimension from these lines to the leading edge of the lower wings in a fore-and-aft, and horizontal direction.

The fin, which is usually fitted on the centre line of the fuselage, may be proved for position by a plumbline and by measuring from the tailplane tips to the top of the fin on each side. The tailplane should be checked

100

for level athwartships and incidence in its two extreme and neutral positions.

The elevators should be examined that they are out of winding, and further that they are interconnected if the aircraft is in the aerobatic category. A plumbline should be hung near to the trailing edge of the rudder to check that the component is vertical. The extreme positions of the rudder, elevators, and ailerons should be checked that they are at least up to the drawing requirements, and that they are in the central positions

Inclination to the horizontal is the angle of INCIDENCE

STAGGER

DIHEDRAL ANGLE

Dotted lines indicate DIAGONAL MEASUREMENTS

AIRCRAFT IN FLYING POSITION
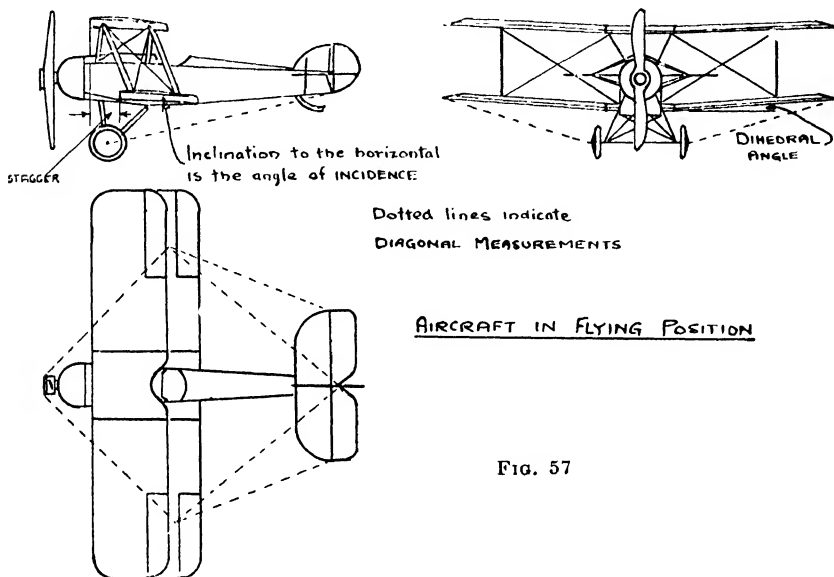
FIG. 57

when the cockpit controls are central. The ailerons should be correctly adjusted for droop (if any).

While dealing with the control surfaces, remember that when the control column is moved to the right, the right aileron moves upwards. When moved back the elevators move upwards. When the rudder bar is pushed forward with the right foot the rudder moves to the right hand of the operator, and when the tail adjusting wheel is rotated in the forward direction the incidence of the tailplane is increased. The slats should operate freely at all positions of their movements.

In order to ensure squareness and symmetrical fitting of the superstructure with regard to the fuselage, the following dimensions, which are known as "diagonals," should be taken—

1. Front or rear outer interplane strut   to sternpost.
2. Front or rear outer interplane strut   to tip of tailplane.
3. Front or rear outer interplane strut   to airscrew hub.
4. Wingtip   to end of undercarriage axle.
5. Sternpost   to end of undercarriage axle.

These dimensions are taken on each side of the fuselage. Additional measurements between other suitable points may be taken if considered necessary.

In the absence of specified limits for angular and diagonal readings, the following general limits are given for guidance—

Front diagonals (3) .	$\pm \frac{1}{2}$ in. up to 20 ft. increasing by $\frac{1}{8}$ in. per 6 ft. increase.
Rear diagonals (1) including (2)	$\pm \frac{3}{8}$ in. up to 25 ft. increasing by $\frac{1}{8}$ in. per 8 ft. increase.
Wingtip to end of under-carriage axle (4)	$\pm \frac{1}{4}$ in. for 12 ft. and greater or less in proportion for other dimensions.
Sternpost to end of undercarriage axle	$\pm \frac{1}{4}$ in. for 15 ft. and greater or less in proportion for other dimensions.
Setting of tailplane fixed	Within $\pm 0^{\circ}$ 15′ of its angular position relative to the mainplane chord.
Moveable . . .	Must have its designed angular movement relative to the mainplane chord within limits of $+ 0^{\circ}$ 30′ $- 0^{\circ}$ at each end of range.
Control surfaces . .	Must have designed angular movements up and down from normal position each within $+ 1^{\circ} - 0^{\circ}$.

Should any of these limits be exceeded the reasons should be investigated by way of examination of the alignment of the components involved.

A definite stage of the final inspection should consist of the examination of all attachment points of components, including—

1. Wing attachments to the fuselage.
2. Wing attachments to the centre sections.
3. All strut attachments to the wings and fuselage.
4. Undercarriage attachment to the fuselage.
5. Tailplane and fin attachments to the fuselage.
6. Rudder and elevator and aileron hinge attachments.
7. Attachments to the wings.

All nuts must be securely locked by split pins or riveting, and all pins requiring split pins should have these inserted and properly opened. All bracing wires should be properly engaged in the threaded fork ends or anchorages. Fairing and cowling attachments must also be examined.

Landing Gear

The undercarriage should be checked for symmetrical disposition with respect to the fuselage by means of trammels or plumblines, which, coupled with the diagonals taken formerly, will ensure that it is satisfactory for wheel track. The wheels should revolve freely, and not be too slack, and must be adequately secured.

If it is a braked undercarriage, tests must be carried out to the design requirements. These tests may involve the application of torque to the undercarriage wheels, and this torque is applied by means of a wooden frame temporarily secured to the periphery of the tyre. The frame is arranged to carry a torque arm, and by applying different weights at the outer end of this arm the actual resistance of the brake may be found in such units as inch-pounds at any stage of application of the brake. (See "Brakes," page 81.)

The tail skid shock-absorbing device should be functioning satisfactorily, and a check of the security of attachment and alignment should be made. If a tail wheel is fitted, it is imperative that an earthing strip should be attached to the landing gear at some convenient point.

FLYING CONTROLS

So important is the satisfactory functioning of flying controls that the duplicate inspection referred to in the following paragraphs must not, under any circumstances, be omitted.

Before assembly into the control system, all details must be fully inspected and bear very clear evidence of that inspection. All cables must be spliced in accordance with the approved standard, and after splicing, but before final fitment to the aircraft, stretched under a tensile load of 50 per cent of the normal breaking load of the cable. Similarly, all roller chains which are a part of the control system, together with the end fittings, must be subjected to a tensile load of one-third of the ultimate load called for on the applicable drawings. Roller chains with spring links are prohibited; only those with a positive method of attaching the links are allowable.

All proprietary articles shall be subjected similarly and invariably to suitable proof loads. If a control wheel is used in the system, the following loads shall be applied—

(a) Push or pull on rim of wheel, the latter supported as in use. Load, 200 lb., applied 100 lb. on each side of the diameter between the spokes.

(b) A tangential force on the rim of the wheel; 75 lb. to be applied between the spokes.

The Inspection Leaflet No. 1 calls for the inspection of all aircraft controls as a duplicated inspectional operation. First, as an operation during assembly of the aircraft, and secondly, as a part of the inspection immediately preceding flight, and Inspection Leaflet No. 17 lays down that both of these stages of inspection must be carried out by different individuals. The following paragraph is extracted word-for-word from Inspection Leaflet No. 17, owing to its importance—

"It must be clearly realized that such duplicate inspection must be carried out invariably after all adjustments have been made. Not only is the functioning to be checked, but each separate control must be followed through from end to end, and a careful examination made of all joints, junctions, and locking devices. If dismantling, or any further adjustment of the controls is carried out thereafter, the above duplicate inspection must be repeated."

While the final inspection of the aircraft is being carried out, it must be at the sole disposal of the inspector, and no work of any kind carried out by the constructional staff.

Should the control system carry parts on which an adequate inspection cannot be carried out, that system should not be approved by the inspector. The following points should receive attention during both of the above-mentioned inspections—

1. That the direction of movements of controlling surfaces are correct in relation to the operating control levers or hand-wheels, and that the control operating levers in dual control aircraft are synchronous. When the control column is central all control surfaces should be neutral.

2. That all motions are free and regular throughout the system, without undue backlash.

3. That all cables lead fairly on to the pulleys or into fairleads.

4. That there is no possibility of the cables over-riding or leaving the pulleys.

5. That there is no possibility of jamming or fouling in any part of the mechanism.

6. That the stringing cord inside the planes is untouched by the controls.

7. That there are no parts likely to work loose and that there is ample locking of all details.

8. That there is sufficient length of thread, etc., in turnbuckles for subsequent adjustment of cables.

9. That no control surface fouls throughout the complete range of its movement.

10. That the tail adjusting gear index plate is graduated consistently with the movements of the adjusting gear.

11. That the pilot will have satisfactory freedom in all reasonable attitudes.

At the conclusion of the above flying control inspection, the necessary records must be made in the aircraft logbook, and signed for by each person making the check.

INSTALLATION OF ENGINE

In approaching this subject, it is first necessary to check that the engine installed is of the type approved for the purpose, and that the logbook indicates that the records are satisfactory. For instance, it would be essential to ensure that if the engine had been damaged while formerly installed in this or any other aircraft, that a certified overhauling was subsequently carried out. The alignment of the mounting has already been dealt with under "Fuselage Construction," but by check measurements taken before and after installation, preferably by trammelling, it can be ensured that no undue distortion has been caused on the mounting structure due to the weight of the engine.

The bedding of the engine on the mounting should be checked and also that the designer's requirements are met with regard to the packing between the engine and mounting. All securing bolts should be of the type called for on the drawing, and properly washered, tightened, and split-pinned or otherwise locked.

It is imperative that such clearances are allowed between the engine and its parts, and the structure of the aircraft, as will guarantee that no contact is made under any vibration while the engine is running.

Starting devices are not generally employed with light civil aircraft, but if used as they are on the larger-engined aircraft security of attachment, freedom of movement, should be carefully noted. The types of starters commonly in use are the hand or electric inertia starters, gas starters, and Hucks starters.

The method of attachment of the airscrew to the engine shaft should be carefully inspected. The assembly of the boss to the airscrew is an important operation. The bolts should be an easy fit in the holes, and the tightening of the nuts evenly carried out so as to take a uniform pressure all round on the boss flanges, that is, the flange should not be drawn more on one side than the other.

When mounting the airscrew, no weight should be taken on the shaft until the airscrew is completely home on the shaft; in other words, do not rely on the nut for pulling into position, or scoring or "picking up" may be the result. After tightening the nut, it should be locked in the approved manner.

After mounting, the airscrew should be checked for "track" in the following manner—

Place a pair of steps or similarly functioning device as near as possible to the tip of one of the blades, which should be approximately horizontal,

and make a measurement to a convenient point on the pitch face of the blade. Then rotate the airscrew, assuming it to be a two-blader, through 180°, and measure to a corresponding point on the other blade.

If the airscrew is comparatively new, the variation in the two measurements should be comparable with those laid down herein for the manufacture of airscrews. When an airscrew has been in service for some time, the variation of $\frac{1}{4}$ in. may be tolerated on an airscrew diameter of 8 ft., or *pro rata* for other diameters.

If the variation is in excess of this latter dimension, the cause of the error should be investigated by way of removal of the airscrew for the re-checking of all the factors involved, and if everything is found to be satisfactory with the airscrew, the positioning of the engine should next be queried.

It is difficult to lay down extreme limits which are hard and fast for airscrew track, for airscrews which are giving satisfactory service in flight may be beyond the above-mentioned limit of error. Incidentally, undue engine vibration due to excess track error may settle the question of the removal of an airscrew.

In the case of a twin-engined or multi-engined machine, a rough check for alignment may be made by placing the airscrews approximately horizontal, and dropping plumb-bobs over the tips of the blades, and at the same distance on each side of each blade, and checking them on to a line drawn through on the floor of the shop.

In order to check whether an airscrew is right-handed or left-handed, the following method may be employed: Place one of the blades in a vertical position above the boss, and standing in a position looking squarely on to the pitch face, the hand of the airscrew will be indicated by the side on which the leading edge occurs, that is to say, if, in this position, the leading edge is on the right hand, then the airscrew will be a right-handed one.

IGNITION SWITCHES AND WIRING

The general lay-out of the ignition system should first be proved to conform to the drawing requirements. The electric cables should not pass over the sharp edges of fittings or ducts, or be in contact with any moving parts which would damage the insulating material. They must be so installed as to avoid accidental damage from persons entering, leaving, or working on the aircraft.

The cables should run in ducts with flared ends wherever possible, and be accessible throughout their lengths. They should not be run in the same ducts as the wires of the lighting or wireless systems.

Terminal blocks should be provided at the junctions of detachable components to facilitate erection on dismantling of the aircraft. In the case of an aircraft with folding wings, the terminal blocks must be so placed as to avoid disconnecting the circuits when folding the wings.

Switches of an approved make are to be so installed that when in the "on" or running position, the levers of knobs are upward, as they work in the opposite way to the standard household switch. The cables should be bared just sufficiently to permit the core well entering the terminal hole. There is a liability of "shorting" if the cables are excessively bared, or if they protrude too far through the terminal hole.

In the case of twin-lever or twin-knob switches, it is advisable to arrange for the port lever to control the port magneto and the starboard lever the starboard magneto. In this manner, if there is a serious drop in engine revolutions when one magneto is cut out, the magneto with its set of plugs is at once determined.

8—(A.3)

The connection of the wires for the terminal blocks should also be examined in this respect.

The tests for electrical continuity and earthing are carried out with the aid of a lamp or bell and battery. Earthing is checked by disconnecting at the contact-breaker, and inserting a lamp or bell and battery in series with this wire, and any portion of the engine to form an earth. With the switch "off," the lamp should light, and be extinguished when the switch is put in the "on," or running position.

ENGINE CONTROLS

A careful end-to-end inspection should be made on all engine controls, which should be positively operated by straight push and pull rods, or torsion tubes. The security of the cranks and levers should be positive, that is, by brazing and pinning, or by the engagement of serrations, as levers operated by friction are not permitted. The cranking of control rods is prohibited unless definitely called for by design. All rods over 3 ft. in length should be provided with guides to prevent bowing, and ensure accurate movement.

Although controls should move with a minimum of friction, they should not be sufficiently loose to move during flight due to vibration. A check should be made for the correct direction of movement of levers both at the operating and engine end of each control. There should be no possibility of fouling throughout the complete ranges of movements.

All controls must operate in forward or upward directions for the opening or running positions and be suitably labelled to show their particular functions, and the "open" and "closed" positions.

There should be ample means of adjustment after all locking has been carried out.

INSPECTION OF HYDRAULIC CONTROL MECHANISMS

Coupled with the necessary checks that the whole of the installations and details thereof are in accordance with the drawing requirements and specifications, and that all previous inspections and releases have been effected, is the ground inspection for satisfactory functioning in all respects.

All pipe lines and internal parts of the system should be perfectly clean, for the smallest particle of foreign matter may cause poor functioning or even failure. Operating jacks should be correctly aligned and electrical circuits tested.

When ground-testing a hydraulic system which has its pressure supplied by an engine-driven pump, it is usual to disconnect the engine pump and connect it to a portable rig whereon it is suitably driven at approximately its normal engine revolutions. In testing the retractable undercarriage, the machine must be jacked clear of the ground. The entire system must be filled with the correct fluid and free from air. To accomplish this, "bleeding" points are provided, and during and after bleeding the fluid in the header tank should be maintained at its correct height. By bleeding at the several points provided, the fluid is allowed to flow in and from the system sufficiently to carry away with it any remaining air. Care should be taken to avoid contact of the fluid with the fabric covering of the aircraft component.

With the undercarriage set in the down position ready for functioning, the inspector should check all joints for freedom from leaks, that all catches are properly locked, that the indicators show the green light, and that the audible warning device is not operating.

During retraction it should be observed that all moving parts have adequate clearance and that there is no possibility of fouling: that the

audible warning device operates when the throttle is in the appropriate position, and that the amber light is showing. See Fig. 57A, which shows a Lockheed indicator.

The specified pressure should not be exceeded, and this should be checked by pressure gauges, which in turn will prove the appropriate functioning of the relief valve. With the undercarriage retracted, the locking catches

AMBER

RED

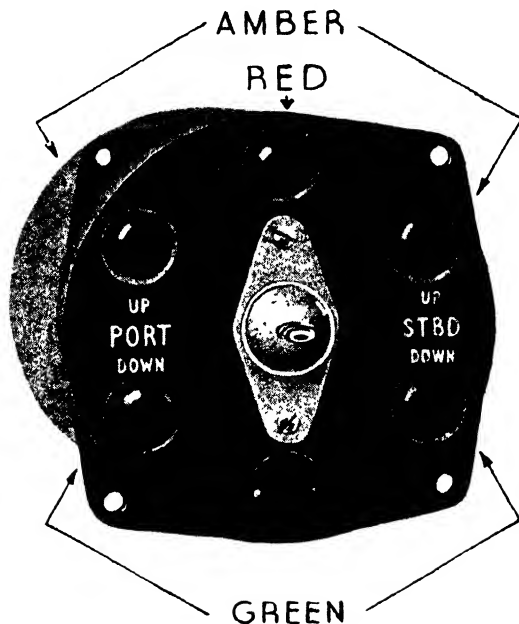UP PORT DOWN   UP STBD DOWN

GREEN

Fig. 57A

should be properly locked, and the red light and amber lights showing. After these tests a re-check should be made for leaks.

After the power-driven tests have been carried out, the undercarriage should be operated in each direction by the hand pump, and then lowered by using the mechanical emergency gear, making similar observations to those made during the power-driven operation.

The flaps should be tested while the undercarriage is in the down position. In functioning, it should be checked that the flaps do not wind, that they function simultaneously and equally, that the indicator records correctly, and that the specified pressure is not exceeded. The hand pump should be tried in like manner to that applied for the undercarriage.

INSPECTION OF FUEL, OIL, AND WATER SYSTEMS

The tanks of any of the above systems, together with connecting and securing parts and bolts, should bear evidence of proper inspection before installation.

During installation of these components, it is well to remember that for repair purposes, or alteration, they may have to be removed, and should be so installed as to facilitate easy removal. They should be so secured as to prevent any movement due to the aircraft landing, or to vibration.

No mounting should be made on any material which is moisture-absorbing, such as felt, without some insulating material being used to protect the tank from corrosion. A clearance of at least $\frac{1}{4}$ in. should be allowed between a tank and any other member or part of the aircraft (apart, of course, from its attachment) to avoid the possibility of chafing or wearing.

All copper piping under 1 in. in diameter should be in the fully softened condition, in which condition it may be bent and worked without further heating. Where heating is requisite, as in the case of large copper pipes, a careful control should be kept of the temperature during the subsequent imperative annealing.

All pipes should be fairly led to their end connections so that they are not pulled or strained into alignment on fixing. They should also be
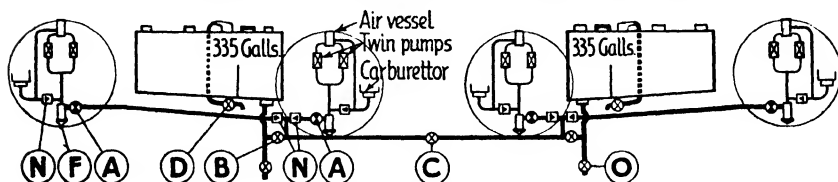

Fig. 57B. The Aw27 Petrol System

A* Engine supply cock   F   Filter
B† Wing-tank cock   N   Non-return valve
C† Tank balance cock   O† Off-loading cock
D† Refuelling cock
            * Operated by Captain.   † Operated by First Officer.

supported at regular intervals by efficient clips. Many pipes have fractured in service due to the neglect of this point, and sometimes with very serious results.

A systematic check should be made of the locking of all joints, filter covers, etc.

All of the three systems should be checked to determine that there is no possibility of air locks, and that the liquid will form one continuous flow through the particular system. Air locks are most likely to occur in pipes having a profile shape of an inverted "U," the air becoming locked in the top of the curve and arresting the liquid flow at that position.

All joints, accessories, and piping should be free from leaks when the system is full. The petrol flow is checked by disconnecting the union nut at the carburettor, and taking a measured flow on a level with the joint, with the aircraft in a climbing attitude, which, for practical purposes, is usually with the tail skid on the shop floor, and the tank under test 10 per cent petrol filled.

Further, if under flying conditions three engines on one aircraft are to be served with fuel from any one tank, then the petrol flow should be taken at the three engines simultaneously. As the result of this test, the fuel supply should be at least 100 per cent in excess of the maximum requirements of the engine or engines, or such less amount than 100 per cent as is officially authorized.

In Fig. 57B is seen a diagrammatic view of the petrol system employed on the "Ensign" type of aircraft (Armstrong Whitworth), with the names of the various parts of the system. It should be noted that each of the two petrol tanks, one port and the other starboard, normally supplies two engines through the engine-driven pumps; but if necessary, one tank will supply all the engines if the balance cock is opened. The tanks are situated in the nose of the wing, one on each side of the fuselage. They

are connected by the long horizontal balance pipe shown in the diagram, with a cock provided in the middle for balancing or isolating the petrol in the tanks as desired.

The fuel does not flow direct to the carburettor, but in each case passes through a non-return valve to prevent surging, then through an engine supply cock (one for each engine) to the filter, thence through the engine-driven pump to the carburettor.

If an engine pump should fail for any reason and impede the petrol flow, it is possible for the fuel to flow by gravity by short-circuiting the pumps. This process is automatic in operation, as there is a non-return valve between the lower ends of the inlet and delivery pipes of the pumps.

If cocks or non-return valves are removed for the purpose of renewal or maintenance, extreme care should be taken to avoid incorrect reassembly, the results of which are very obvious. External indication of direction of flow, "on," and "off" is invariably provided on the accessory.

To carry out a petrol-flow test with such a system as this, it is usual to employ a pump rig. This rig consists of a petrol pump driven so as to supply the same quantity of fuel as that supplied by the engine pump when the engine is doing maximum revolutions per minute. The pump should be placed on the same level as the engine pump, and the supplementary piping of equivalent bores and runs to the engine piping connected into the petrol system to enable the flow to be taken at the carburettors as it would with the engine pump functioning. This should prove that the petrol supplied is at least equal to that required by the design authority.

Pumps which are fitted as parts of the aircraft, that is, as apart from those which may be incorporated in the engine, should be spun at their normal flying revolutions, and checked for functioning and supply. The method of spinning is usually that of connecting the pump spindle to the driving shaft of a suitable motor.

Oil coolers should be checked especially for assembly, and that the oil has a clear passage through the cooler.

The water system should be inspected throughout for leaks and all parts for security of attachment.

If a retractable radiator is fitted it should be examined throughout the whole range of movement.

ELECTRICAL SERVICES

All candidates should acquaint themselves with the simple formula $C = \dfrac{E}{R}$ where C = amperes, or units of current; E = volts, or units of electromotive force, and R = ohms, or units of resistance. (One megohm = 1,000,000 ohms.) With this formula well understood, it is easier to go ahead on electrical testing.

In testing electrical circuits for insulation resistance, a 500 volt megger should be used. The minimum resistance registered when testing between any two poles should be 2 megohms. It is usual, however, when testing for insulation resistance "between poles," to bunch all leads connected to the red terminal of the voltage control box, and apply the formula $\dfrac{20 \text{ megohms}}{\text{No. of points in circuit}}$, the value of which should exceed 2 megohms.

Circuits under test should be closed at the switches but have lamp bulbs and similar detachable items removed.

If the figure obtained is unsatisfactory, more local tests should be

carried out to discover the exact position of the breakdown, in order that the wire or part may be replaced.

In testing for continuity of wiring, a battery should be used with a lamp or bell as an indicator.

An aircraft which has to be fitted for wireless should have all of the metallic parts metallically bonded, and the aircraft should be checked for this from one component to another, say from wingtip to wingtip and from rudder to interplane strut, etc. The Inspection Leaflet dealing with this subject should be carefully studied, and all the points mentioned therein should receive due attention.

INSTALLATION OF INSTRUMENTS AND EQUIPMENT

In the majority of cases nearly all aircraft instruments are secured to a main instrument board, and should be so placed that the pilot can read them without undue effort when seated in a normal flying position. The instrument board should be adequately secured and free from any undue vibration in flight. or when the engine is ground running.

All instruments installed must be of approved types. The question of the approval of the type of an instrument may be overlooked due to an inspector's keenness to attend to the question of an instrument having passed approved inspection. Both points are important, however.

As approximate checks can only be made on instruments after installation, unless portable calibrators are available, the question of approval and certification of satisfactory calibration before attachment in the aircraft is all the more important. Instruments are usually released and fully certified for functioning by a firm whose inspection organization has been duly authorized, but failing this, no instrument should be used before being tested and certified at an approved test house. If at any time there is doubt regarding the satisfactory functioning of an installed instrument, it should be removed and properly calibrated.

The following observations or checks should be made when inspecting the equipment in the aircraft, in addition to checking that the instruments are properly secured and all joints are tight.

AIRSPEED INDICATOR. Apply a slight air pressure, say by blowing down the pressure tubing at the pressure head end, and hold this pressure for about half a minute. During this time the indicator needle should remain stationary. If, when blowing down the tube the needle moves in the wrong direction, the Pitôt tubes are wrongly connected. A standard water gauge or portable calibrator may be used to check an airspeed indicator if the accuracy is suspected.

ALTIMETER. The milled knob at the bottom of this instrument should be turned to see that the dial is rotated satisfactorily by the pinion on the racked periphery. If the instrument is suspected of functioning wrongly in flight, it should be removed and calibrated.

PRESSURE GAUGES. When not functioning, the indicators should stand at zero. Further checks may be made when the engine is running by applying pressure in the fuel tanks, etc., or by the use of a portable calibrator.

THERMOMETERS. These may be roughly checked for comparison against the temperature in the shop or hangar where the range of the instrument includes the temperature of the atmosphere. In the case of radiator or oil temperature thermometers, the connection and securing of the capillary tubes should be carefully examined.

ENGINE REVOLUTION COUNTER. This should stand at its lowest reading when the engine is not running. The flexible drive should be installed with

as few bends as possible, and no bend should have a radius of more than 9 in. The connecting ends of the drive to the gearbox and the instrument should be examined.

CROSS LEVEL. The bubble should be central when the aircraft is level athwartships.

TURN INDICATORS. The makers' instructions should be carefully followed regarding the fitting of any particular indicator, but the aircraft should always be in flying position during fitment in order to check that the instrument is correctly levelled and squared.

COMPASS. An installed compass should be examined for—

1. Pivot friction. This is done by deflecting the magnet system through approximately 5° with the aid of a corrector magnet. When this magnet is removed, the magnet system of the compass should return easily to its original position.

2. Discoloration of the liquid, and that the card is easily readable. The liquid should be free from bubbles.

3. That the anti-vibrational devices supporting the bowl are in good condition. The bowl should not foul any part of the aircraft.

4. That the compass is supported on a level platform, and that no ferrous metals are used for supports or security. No ferrous metal fittings should be so close as to cause errors in the readings.

5. The corrector box should be placed under the centre of the compass with the magnet holes positioned fore and aft and athwartships.

SAFETY BELTS AND HARNESS. The regulations regarding this equipment should be carefully observed. Every belt should be proof loaded before fixing in the aircraft. Two-piece belts should be so attached in the aircraft as to prevent slipping downwards from the chest to the abdomen.

All attachments and fittings connecting the belts to the aircraft should be capable of withstanding a load consistent with the strength of the belt.

The use of leather as a material for safety belts is prohibited.

CENTRE OF GRAVITY OF AN AIRCRAFT

The Air Navigation Directions lay down that every flying machine shall be weighed to the satisfaction of the Secretary of State before a Certificate of Airworthiness (C. of A.) is issued in respect thereof, and at such times after the issue of a C. of A. as the Secretary of State may require. Every flying machine for which a C. of A. is in force shall bear clearly painted upon it in a prominent position, its weight empty, or tare weight, including the water in the radiators, as ascertained at its last weighing, and the maximum total weight authorized for it as shown in its C. of A. In addition, the machine must carry displayed in a prominent position inside it a weight schedule showing what items of equipment, if any, were included in the weight empty, or tare weight.

With reference to the loading of an aircraft, it is important from a safety point of view that for any particular load up to and including the maximum permissible, the centre of gravity shall be within the range stated in the Certificate of Airworthiness for the aircraft.

The position of the centre of gravity of an aircraft will be determined in terms of its relative position to the chord of the aircraft bottom plane, or to the datum point and the datum level if the C.G. range is stated in these terms—

1. The longitudinal position of a plane perpendicular to the chord and containing the C.G. will be determined in terms of inches measured along

the chord line either in front or behind the leading edge, or, similarly, behind or in front of the point fixed as the datum point on the aircraft.

2. The vertical position of the C.G. will be determined in terms of its perpendicular height in inches above or below the chord line or datum line.

3. The transverse position of the C.G. is always assumed to be in the plane of symmetry of the aircraft.
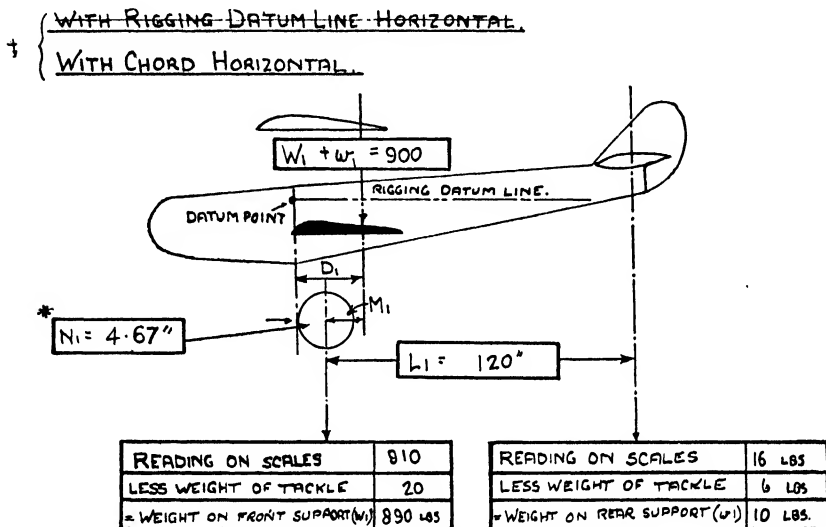

FIG. 58

The method of determining the longitudinal position of the C.G. is given in the following paragraphs.

The C.G. is first calculated from figures obtained by weighing the aircraft in the tare condition, that is, the completed aircraft less pilot, passengers, petrol, oil, and all removable equipment, but with the water in the radiators (if any). In this condition the aircraft is placed with its landing wheels and tail skid or wheel on scales so that it is in such a position that its datum line is in an horizontal position, or set so that the longitudinal plane containing the chord line of the bottom main planes is horizontal.

The C.G. is then calculated as laid down in the diagram shown in Fig. 58. When the front support is horizontally in front of the leading edge or

$$M_1 = \frac{w_1 \times L_1}{W_1 + w_1} = \frac{(10) \times (120)}{(890 + 10)} = 1 \cdot 33 \text{ in.}$$

The distance that the plane containing the tare C.G. is behind the *leading edge } is—
  datum point }

$$D_1 = M_1 + N_1 = (1 \cdot 33 \text{ in.}) + (4 \cdot 67 \text{ in.}) = 6 \text{ in.}$$

datum point, this measurement corresponding to N_1 in the diagram should be expressed as a negative value. All measurements must be taken on both the port and starboard sides of the aircraft, and from these the

* Delete where inapplicable.

mean values are calculated. If a negative load occurs at w in the zero angle of incidence, or when the datum line is level, an extra moment may be added for convenience in order to stabilize the aircraft in that position, and subsequently deducted in the calculations.

Having determined the tare C.G., the C.G. for any specified loading may be calculated as shown in Table III. It must be clearly understood that when the aircraft is levelled to the rigging datum line, the measurements are made from the datum point, and the position of the C.G. registered therefrom, but if the chord line of the mainplane is used, then the measurements are correspondingly made from the leading edge, and the C.G. referred to this point.

In the diagram and table, simple illustration figures have been inserted to facilitate explanation. It will be seen that the position of the horizontal C.G for the particular loading is obtained by dividing the resultant moment by the total load and in this case is 6·9 in. behind the leading edge.

For purposes of calculation, the following weights should be used—

Weight of fuel	. .	7·7 lb. per gallon
Weight of oil	. .	9·7 lb. per gallon
Weight of crew	. .	170 lb. per person

When estimating approximately the number of passengers who may be carried for the commercial load available, the average weight of a person may be taken as 170 lb.

* When the front support is horizontally in front of the †$\left\{ \begin{array}{l} \text{datum point} \\ \text{leading edge} \end{array} \right\}$ this measurement is to be expressed as a negative value.

† Delete where inapplicable.

TABLE III

Correction of Tare C.G. for the Undermentioned Loading

LONGITUDINAL ALONG *{ Rigging Datum Line / Chord Line Position of Load and its Moment

In Front of *{ Datum Point / Leading Edge		Behind *{ Datum Point / Leading Edge		Load	Weight in Lb.
Distance in Inches	Moment (in lb.)	Distance in Inches	Moment (in lb.)		
		6	5,400	Aircraft (Tare)	900
		40	6,800	Pilot	170
		1	170	Passenger	170
6	1,800			Petrol	300
3	180			Oil	60
		20	1,000	Luggage or any other Loading	50
	1,980		13,370	Total Weight	1,650
			11,390	Resultant Moment (larger moment minus the smaller)	
		6·9		C.G. Position Resultant Moment / Total Weight	

* Delete where inapplicable.

APPENDIX

GLOSSARY OF AERONAUTICAL TERMS

Extracted from

THE BRITISH STANDARD GLOSSARY OF AERONAUTICAL TERMS

By kind permission of the British Standards Institution, 28 Victoria Street, London, S.W.1, from whom copies of this Glossary and all B.S. Specifications can be obtained.

Acorn. A device introduced at the intersection of bracing wires to prevent abrasion.

Adjusting Gear for Aileron, Rudder, Fin, or Tailplane. Mechanism provided for altering the trim of the control surface during flight.

Aerobatics. Evolutions voluntarily performed with an aircraft other than those required for normal flight.

Aerodyne. A generic term for aircraft which derive their lift in flight chiefly from aerodynamic forces.

Aerofoil. A surface designed to produce an aerodynamic reaction normal to the direction of motion.

Slat. An auxiliary aerofoil forming the forward portion of a slotted aerofoil with forwardly located slot.

Aerofoil Section. The outline of the section of an aerofoil in a plane parallel to its plane of symmetry.

Aeroplane. A flying machine with fixed wings.

Amphibian. An aeroplane provided with means for normally rising from, and alighting on, either land or water.

Landplane. An aeroplane provided with means for normally rising from and alighting on land.

Seaplane. An aeroplane provided with means for normally rising from and alighting on water.

Float Seaplane. A seaplane provided with floats as its means of support on water.

Flying Boat. A seaplane of which the main body or hull is also the means of support on water.

Ailerons. Movable flaps situated at or near each wingtip and designed to impart a rolling motion to the aerodyne by their rotation in opposite senses.

Aircraft. All types of air-supported vehicles.

Airscrew Hub. A detachable metal part by which a complete airscrew is mounted on the airscrew shaft.

Airscrew. I—Generically, all types of screw with helical blades designed to rotate in air.

II—Specifically, a power-driven screw designed to produce thrust by its rotation in air.

Pusher Airscrew. An airscrew designed to produce compression in the airscrew shaft.

Tractor Airscrew. An airscrew designed to produce tension in the airscrew shaft.

LEFT-HAND AIRSCREW. An airscrew revolving counter-clockwise to an observer behind the aircraft.

RIGHT-HAND AIRSCREW. An airscrew revolving clockwise to an observer behind the aircraft.

Note. In a tractor system the "hand" of the airscrew is the same as that of the engine, but in a pusher system it is the opposite.

SWIVELLING AIRSCREW. An airscrew capable of being turned so as to transmit thrust in any direction within a fixed plane.

VARIABLE-PITCH AIRSCREW. An airscrew whose blades are so mounted that they may be turned about their axes to a desired pitch while the airscrew is in rotation.

Note. This term is not to be used for an airscrew whose blades are adjustable only when stationary.

Air Speed. Speed relative to the air, as distinct from speed relative to the ground.

Airworthy. Complying with the prescribed regulations for a Certificate of Airworthiness.

Angles. Aileron angle—Elevator angle—Rudder angle. The angle between the chord of the movable portion of an aerofoil and the chord of the corresponding fixed surface.

ANGLE OF INCIDENCE (RIGGING). The angle between the chord line of the mainplane and the horizontal when the aeroplane is in the rigging position.

Note. Not to be confused with the true Angle of Incidence, which is the angle between the chord line of an aerofoil and the relative wind.

ANGLE OF SWEEP-BACK. The angular set back of the mainplanes relatively to the fuselage or hull.

DIHEDRAL ANGLE. The angle at which both port and starboard planes of an aeroplane or glider are inclined upwards or downwards to the transverse axis. The dihedral angle is the acute angle between the span axis of either plane, and the transverse axis. If the inclination is upward the dihedral is positive.

TAIL-SETTING ANGLE. The acute angle between the chord line of the mainplane and the chord line of the tailplane. If the latter is at a greater inclination to the horizontal than the former the angle is said to be positive.

Aspect Ratio. The ratio of the span to the mean chord of an aerofoil, i.e. the ratio of the square of the maximum span to the total area of an aerofoil.

Balanced Surface. A control surface which extends on both sides of the axis of the hinge or pivot in such a manner as to reduce the moment of the air forces about the hinge. The portion of the surface in front of the hinge is referred to as the "balance" or "balance portion."

Banking. Angular displacement about the longitudinal axis for the purpose of turning.

Boss. The central portion of the airscrew by which it is attached to the airscrew hub or shaft.

Cabane. A pyramidal arrangement of struts on an aerodyne. (Sometimes called Pylon.)

Camber. Curvature of a surface of an aerofoil.

Ceiling.

ABSOLUTE CEILING. The height at which the rate of climb would be zero in Standard Atmosphere under specified conditions.

SERVICE CEILING. The height at which the rate of climb has fallen to a certain defined limit (e.g. 100 ft. per minute).

Centre Section. The central portion of the mainplane. (Top or bottom.)

Chord or Chord Length. The length of that part of the chord line which is intercepted by the aerofoil section.

Chord Line. The chord line is the straight line through the centres of curvature at the leading and trailing edges of an aerofoil section.

Note. In the past the term Chord Line has been used as indicating the common tangent to the bottom surface of an aerofoil. The new definition has been adopted for precision.

Control Column. The lever or pillar supporting a hand-wheel by which the elevator and aileron controls are operated.

Elevator. A movable horizontal surface for controlling the motion of an aerodyne in pitch.

Fin. A fixed vertical surface affecting the lateral stability of the motion of an aerodyne. When fitted at the rear end of the body it is termed the tail fin.

Flap. A hinged rear portion of an aerofoil.

Fuselage. The main structural body of an aerodyne, to which the mainplanes, tail unit, etc., are attached.

Gap. The distance between a plane and the one immediately above or below it.

Leading Edge. I—The forward edge of a streamline body or aerofoil.
II—The structural member there situated.

Levers. Aileron lever—Elevator lever—Rudder lever. The lever arm by which the control surface is connected to the actuating mechanism.

Nose heaviness. A tendency of an aircraft to pitch down by the nose in flight.

Overhang. I—The extent to which the wingtip of one of two super-imposed planes projects beyond the tip of the other.
II—The distance from the outer point of support to the tip of an aerofoil.

Pay (or Commercial) Load. That part of the useful load from which revenue is derived—i.e. passengers, mails, and freight.

Pitch. EXPERIMENTAL MEAN PITCH. The distance through which an airscrew advances along its axis, during one revolution, when giving no thrust.

GEOMETRIC PITCH. The distance which an element of an airscrew blade would advance in one revolution when moving along a helix to which the chord of that element is tangential.

Note. The geometric pitch of an element distant two-thirds of the tip radius from the axis of rotation is usually referred to as the "pitch" of that particular airscrew and is marked on it.

Pressure Head. A combination of pitot and static pressure tubes for use in conjunction with a differential pressure gauge for determining the speed of a current of air.

Rigging. The relative adjustment or alignment of the different components of an aerodyne.

RIGGING POSITION. The position in which, with the lateral axis horizontal, an arbitrary longitudinal datum line is also horizontal.

Rudder. A movable vertical surface for controlling the motion of an aerodyne in yaw.

RUDDER POST. The main vertical member of a rudder to which the rudder hinges are attached.

Rudder Bar. The foot-bar by means of which the rudder is operated.

Servo Control. A control devised to reinforce the pilot's effort by an aerodynamic or mechanical relay.

Sheathing. Thin sheet-metal or other material attached to the tips and leading edges of wooden blades to prevent abrasion by water, sand, etc.

Slipstream. The stream of air discharged aft by a revolving airscrew.

Span. The overall distance from wingtip to wingtip.

Spinner. A streamline fairing fitted co-axially, and rotating with the airscrew.

Stability. The quality by virtue of which any disturbance of steady motion tends to decrease. A given type of steady motion is stable if the aircraft will return to that state of motion after disturbance without movement of the controls by the pilot.

LATERAL STABILITY. The stability of the motions out of the plane of symmetry, i.e. of side-slipping, rolling, and yawing.

LONGITUDINAL STABILITY. The stability of the motions in the plane of symmetry, i.e. of the rise and fall, forward motion and pitching.

Stagger. When one of two superposed planes is disposed ahead of the other, the planes are said to be staggered. When the top plane is ahead of the bottom the stagger is said to be positive.

Stall. To be at or above the angle of incidence corresponding with the maximum lift coefficient of an aeroplane.

Static Unbalance. An airscrew is in static unbalance if, when concentrically mounted on a spindle supported by knife edges, it will not remain at rest in all positions.

Stern Post. The rearmost upright member of the fuselage or hull of an aerodyne.

Note. Not to be confused with Rudder Post.

Strut. A structural member intended to resist compression in the direction of its length.

DRAG STRUTS. Struts incorporated in the framework of an aerofoil to carry the loads induced by the air forces in the plane of the aerofoil.

INTERPLANE STRUTS. Vertical or inclined struts connecting the spars of a plane to those of the plane above.

JURY STRUT. A strut inserted to provide temporary support for a structure. A common example is the strut used to support the wing structure of an aerodyne during folding.

Tail Heaviness. A tendency of an aircraft to pitch down by the tail in flight.

TAIL-SKID. A member taking the weight of the rear end of the fuselage on the ground.

TAIL-SKID BAR. The crosspiece on a steerable tail-skid.

TAIL-SKID SHOE. A replaceable covering on the end of a tail-skid to take the wear.

Tail Wheel. A small wheel sometimes fitted in place of a tail-skid.

Taxying. Movement of an aircraft under its own power, in contact with the earth.

Townend Ring. A ring of aerofoil section arranged round a radial engine to reduce its drag by deflecting inwards the air flowing past it.

Trailing Edge. I—The rear edge of a streamline body or aerofoil.

II—The structural member there situated.

Undercarriage. That part of the alighting gear which embodies the main wheels, skids, or floats.

Useful Load. The gross weight less the tare weight.

Wash-in. Increase of angle of incidence towards the wingtip.

Wash-out. Decrease in angle of incidence towards the wingtip.

Weights. FLYING WEIGHT. The total weight of an aircraft at the beginning of a flight.

GROSS WEIGHT. The maximum flying weight of an aircraft permissible under the Regulations obtaining.

Note. For civil aircraft this is the maximum authorized weight shown on the Certificate of Airworthiness.

TARE WEIGHT. The weight of an aerodyne complete in flying order with water in the radiators, but no crew, fuel, oil, removable equipment or pay load.

Wires. DRAG-WIRES. Wires or cables the principal function of which is to transfer the drag of the planes to the body or other part of the structure.

ANTI-DRAG WIRES. Wires to resist forces in the opposite direction to the drag.

INCIDENCE WIRES. Wires or cables bracing the mainplane structure in the plane of a pair of front and rear struts.

LIFT WIRES. Wires or cables the principal function of which is to transfer the lift of the wings to the body or other part of an aerodyne. (Sometimes called Flying wires.)

Yawing. Angular motion about the normal axis.

I A N DATE OF ISSUE